SCIENCE AND YOU

BOOK III

THE GROWTH OF SCIENCE

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BOOK I: From Simple Experiments
BOOK II: Man uses his Discoveries
BOOK IV: Science Today

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FOREWORD

THIS is the third book in the series of four, intended principally for Secondary Modern Schools. In Books I and II the development of science from simple observations and experiments was made clear, and this book continues in this theme, showing how the study of colour has led to discoveries used in such differing fields as stage lighting, the cinema and the streets. Our accumulating knowledge on combustion has helped the miner, and at the same time has warned us of the waste and the danger in the use of uncontrolled coal fires. A better understanding of the needs of plants and animals leads us to ways and means of supplying these essentials so that we are ensured of the greatest benefit. For the animals I have taken Man as the basic type since he is the animal that concerns us all.

Simple machines have been used by man for many years, so that effort is directed to better advantage. The lever has been in use since its discovery by early man, and the later invention of the pulley is in use in nearly every piece of machinery today. The knowledge of the effects of an electric current has brought about the design of the electric motor, which has so many uses today, as well as many ways of measuring the current.

In this book, as in the two earlier ones the practical side rather than the theoretical side of all these discoveries has been stressed. The interest of the pupil, which I hope is already aroused, will be maintained by the amount of practical work suggested in this book, but once again I would like to say that the experimental side of the subject should not be confined to that contained within these covers.

As on the former occasions I must express my thanks to all those who have helped me, to my wife who has made many suggestions both for inclusion in the text and for its improvement, to Mr. Alan Hall, M.Sc., for his interest and help, to Mr. J. B. Knight, L.D.S., R.C.S., R.N. (Retd), to Mr. A. Stocking for his patience and interest in the making of models, and finally to Mr. R. Hartridge of the Burnt Ash Library, Bromley.

G. E. J. R.

NOTES FOR TEACHERS

The material in this book is not divided into the conventional chapters; but to assist teaching it will be found that the subject-matter falls into the following divisions:

pages	
5–41	*Air and Combustion, Heat and change of state*
42–65	*Mechanics*
66–87	*Electricity*
88–103	*Light and Colour*
104–131	*Human Body*
132–153	*Plant Life*
154–156	*Revision and Conclusion*

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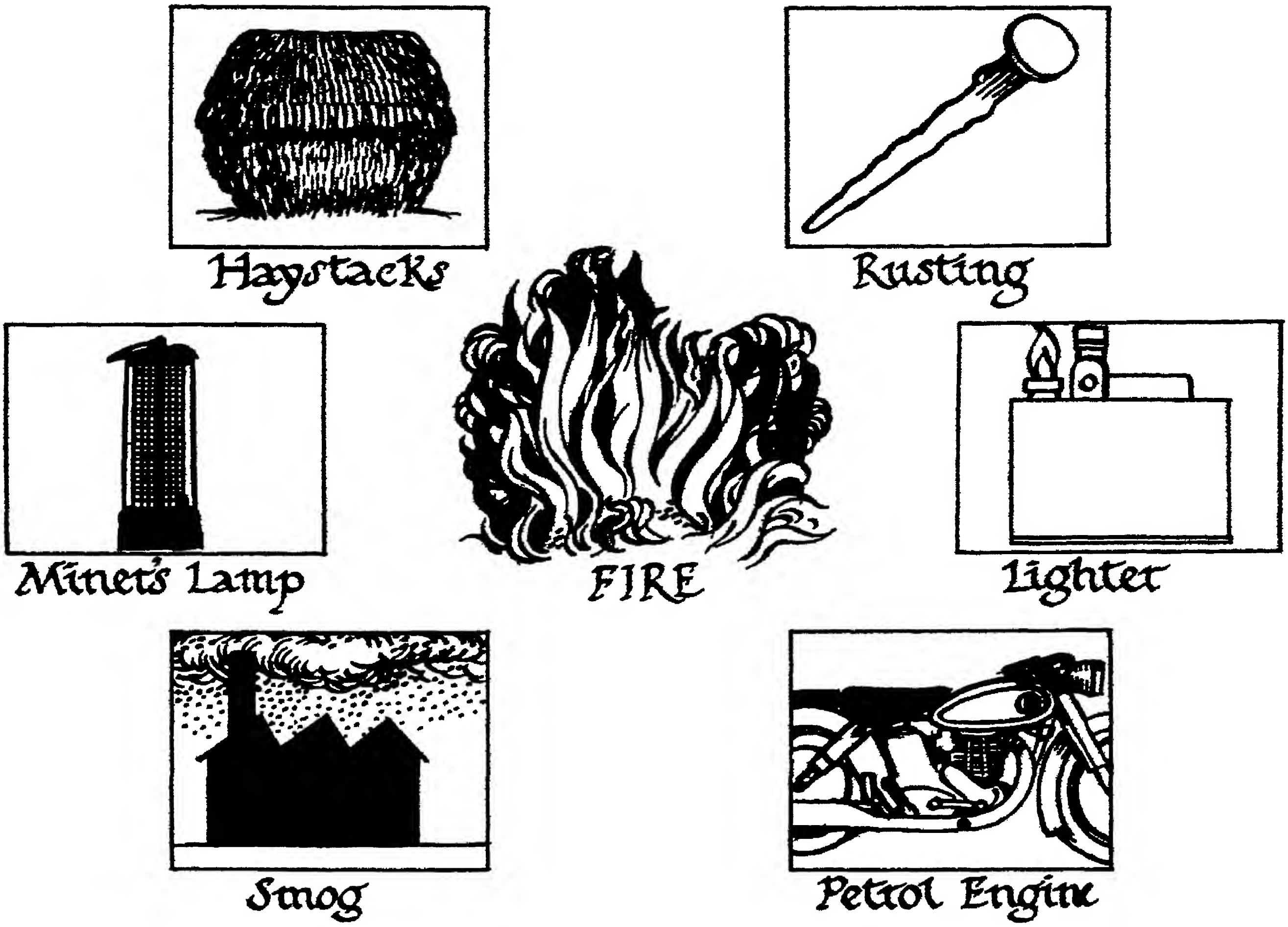


MAN'S GOOD SERVANT: FIRE

FOR many hundreds of years it was thought that everything, including man, was made up of four substances: Earth, Air, Fire and Water. These were called elements because it was thought that each of them contained nothing but itself. But with the increase of knowledge we have found that this view is mistaken.

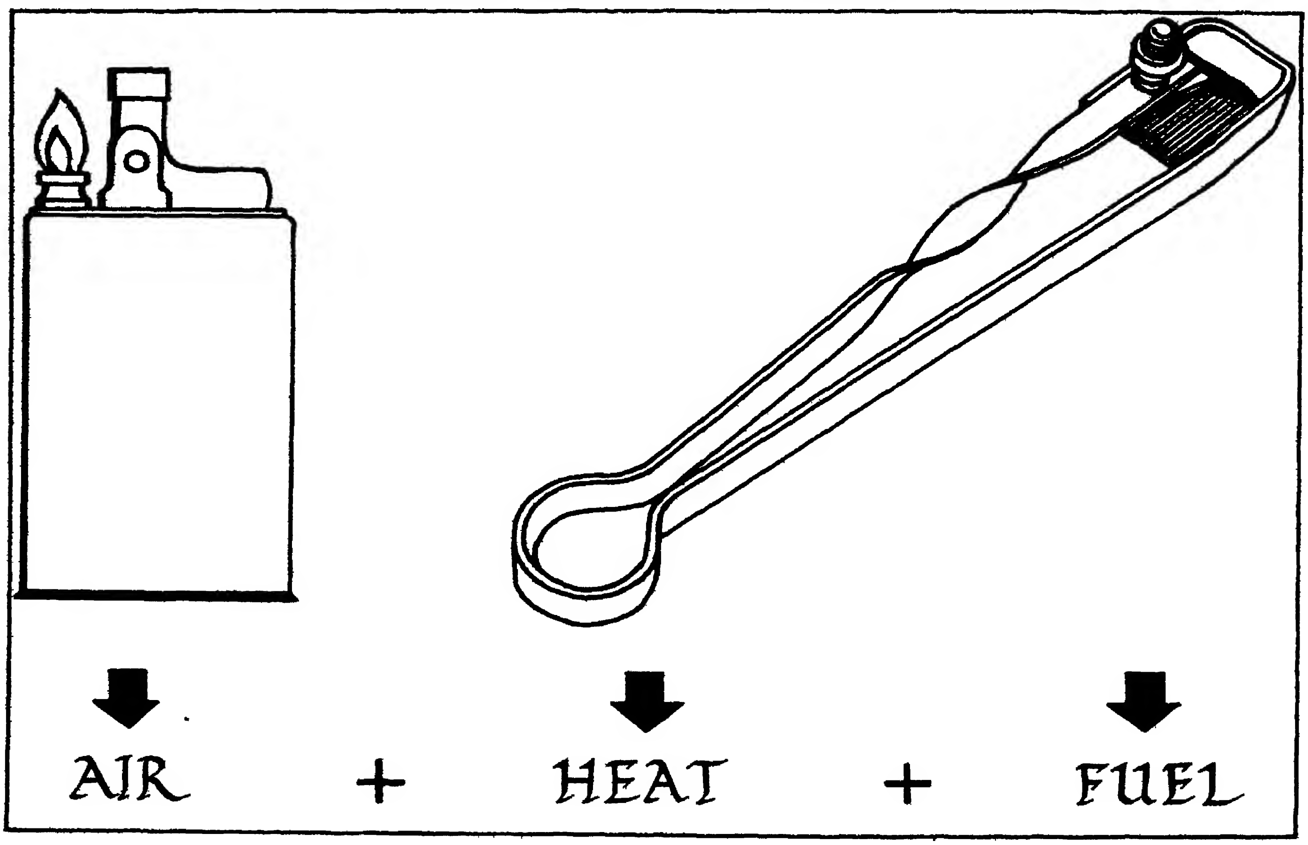
At one time fire was considered to be the most important element, because it is the active part of so many changes. For instance, it was needed for cooking, and was used in the extraction of metals from their ores, and in the tempering of metals too. It was used in many arts and crafts, for example pottery. Fire and the heat associated with it play an important part in our lives today; and, although the heat from fire has in some cases been replaced by heat from electricity, it is still vital to our everyday life. But what is fire? Flame? Burning? How can we control it? Can you say what all these illustrations have in common?

FRICTION IS NECESSARY—

EARLY man made fire by rubbing two sticks together. There are some primitive people, among them the Aborigines of Australia, who still make fire in this way. Have you ever tried to do it? It is no simple task unless you know the "knack".

Later on the tinder-box was developed, and the old pistols and muskets made use of the same idea. A piece of flint, held in a metal clamp, was rubbed on a roughened surface in such a way that sparks of hot flint fell either on to dry tinder or gunpowder. The modern cigarette lighter still works on the same principle, but an artificial flint is used. It rubs against a roughened metal wheel and sparks fall on to a wick which is soaked in petrol. The wick replaces the tinder, but it is the petrol vapour, not the wick, which catches fire.

The ordinary gas lighter is not unlike the petrol lighter. For the artificial flint is used, again against a rough surface, and the sparks or tiny hot pieces of flint ignite or light the gas. Even the everyday match has to be rubbed on a certain rough surface before it catches alight. In



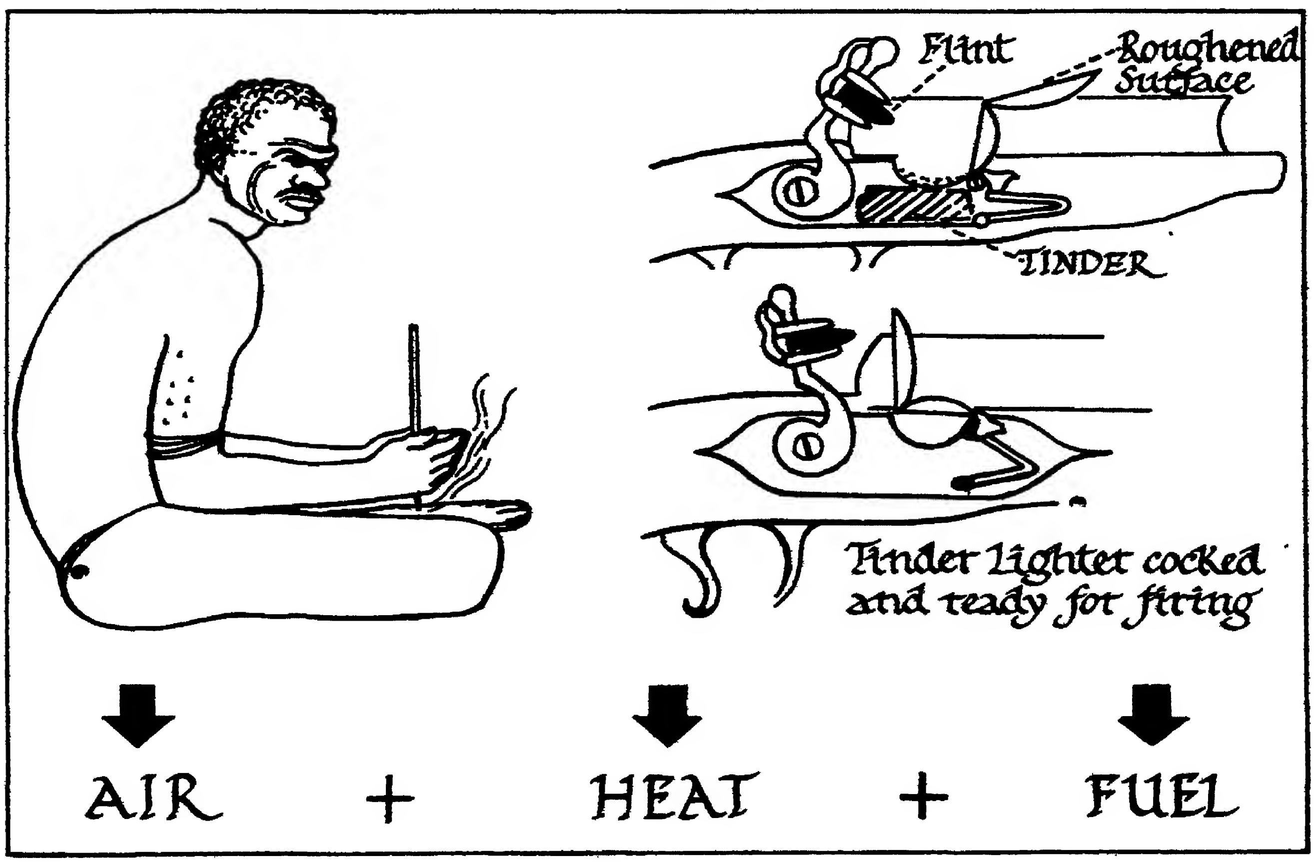
—FOR MAKING FIRE

this case it is the match head that lights. All these forms of making fire have one thing in common. What is it?

Do you remember that in talking about the axle box we said that when two surfaces are rubbed together heat is given out? Consequently the oil in the box was melted and so ran on to the bearings and lubricated them. It is this rubbing that all these methods of making fire have in common. We call it "friction". Friction produces heat; when we have friction together with something that will burn easily we get fire. The tinder, the gunpowder, the petrol vapour, and the gas all burn easily. We say that these substances are inflammable. In the case of the match the inflammable material is on the match head.

But before any of these things will burn there is something else needed. We have talked about this before. Can you say what the other thing is? Think about the ways of controlling a burning fire.

Make a collection of pictures illustrating the various ways of making fire, or copy those here into your Record Books.



TAKING THE OXYGEN—

WE have seen that the air supply to a fire can be controlled. When the air is cut down the fire burns slowly, and when it is increased it burns more fiercely, and when air is cut off altogether the fire goes out. Before anything can burn air must be present. We said earlier that air is a mixture of gases. It is made up of oxygen, nitrogen, carbon dioxide and various inert or inactive gases; water vapour is present too.

In the year 1774 Joseph Priestley discovered the gas called oxygen; and he found that any substances that burnt in the air will burn more strongly in oxygen. On the other hand substances that burn in the air will not burn in nitrogen which is also found in the air. Air consists mainly of oxygen and nitrogen, and it is true to say that in about five parts of air there are roughly four parts of nitrogen and one part of oxygen. So the nitrogen dilutes the oxygen and, of course, the effects of it.

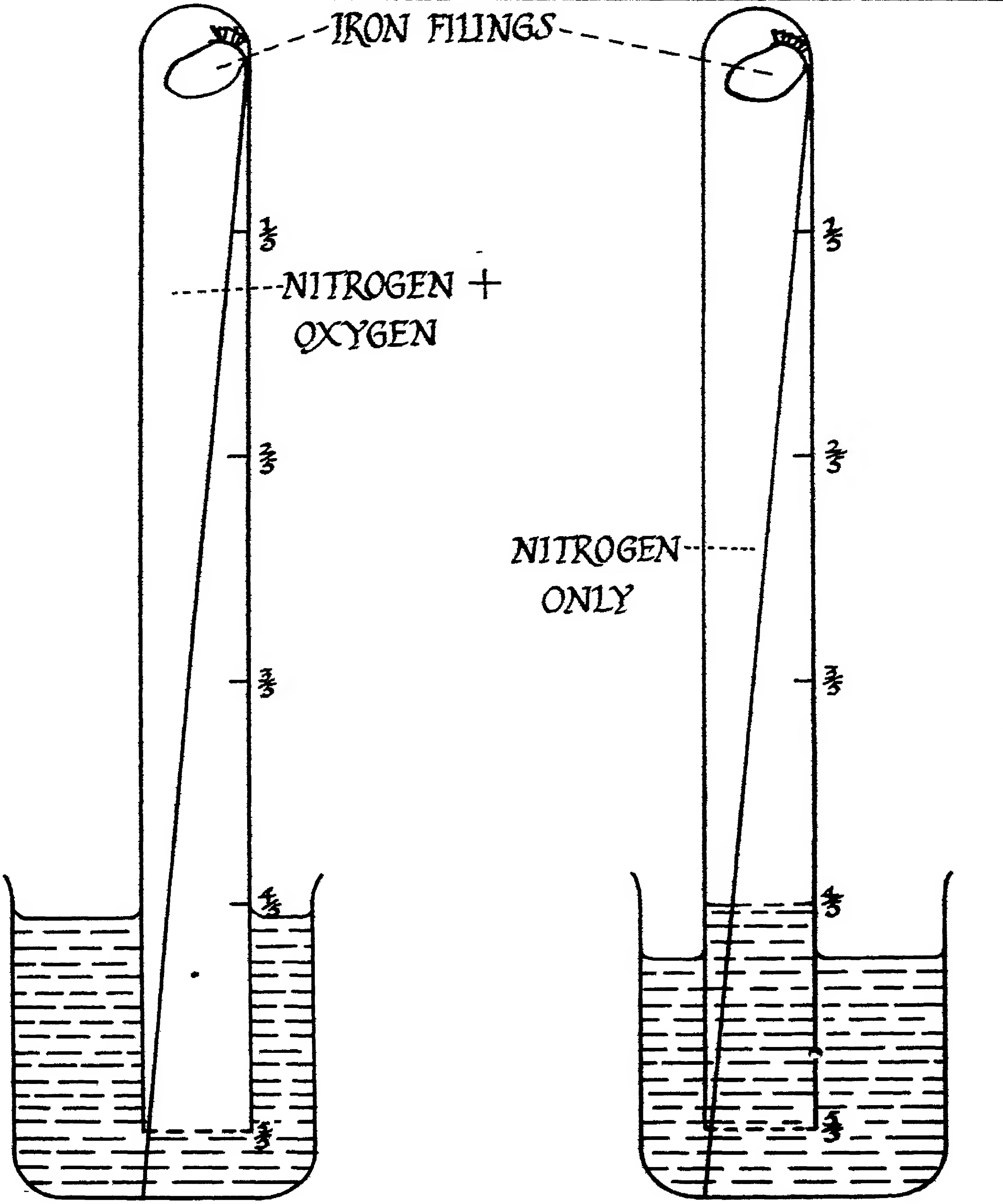
Here is an experiment which shows this fact. On a long glass tube which is closed at one end, stick strips of paper to mark it in fifths of its volume. Put some iron filings into a small muslin bag and support it on the end of a copper wire inside the tube as shown in the diagram. Now stand the tube in a jar or pan of water, first moistening the iron filings. After a while the water level in the tube will begin to rise. If you leave your experiment set up for several days the water will go on rising and then stop. Make a note of the level of the water as it rises throughout the experiment. By how much has the water risen in the tube? Why do you think it has done this?

Now if we test the part of the air left in the tube with a burning taper what will happen? Try it for yourself. Can you explain the result, and do you know where the oxygen has gone to?

When iron rusts it uses up the oxygen in the air, and we say the oxygen combines with the iron to form iron oxide, or rust. Rust is the cause of a great deal of waste and we shall see later how we can protect iron and steel so that rusting is, if not prevented, slowed down.

Next time we shall prepare some oxygen for ourselves, and see as Priestley did what the effects of oxygen are on the burning of substances.

—OUT OF THE AIR



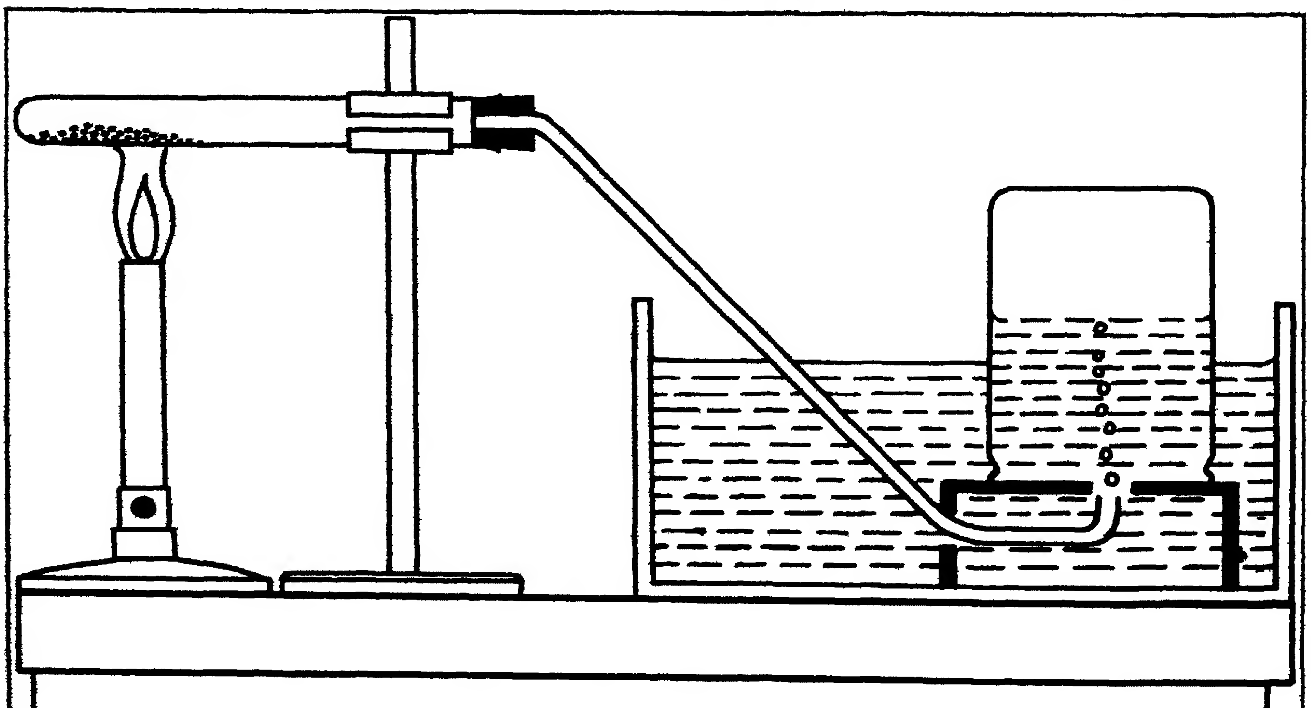
Water rises to take the place of the Oxygen which has combined with the iron to form rust

THE RUSTING OF IRON—

OXYGEN can be obtained by heating certain substances and collecting the gas that is given off. One of these substances is mercury oxide, which contains mercury and oxygen. It was this substance that Priestley used when he first made the gas. Today we shall use permanganate of potash; its chemical name is potassium permanganate. Set up your apparatus as in the diagram here, using a hard glass test-tube fitted with a delivery tube. Heat gently and collect the gas in jars, jam jars will do. When there is no longer any gas given off, remove the delivery tube before stopping heating. This is important: why? Now you have some oxygen to experiment with. Slide some glass covers over the open ends of your jars of oxygen to keep the gas in, before removing them from the trough of water.

Support a candle on a length of wire and light it, remove the cover from one jar of oxygen and plunge the candle in. How does the flame compare now with the flame when it was burning in the air?

Light a wooden spill and blow out the flame so that the end is glowing. Plunge this into a jar of oxygen and watch what happens.



The preparation of Oxygen

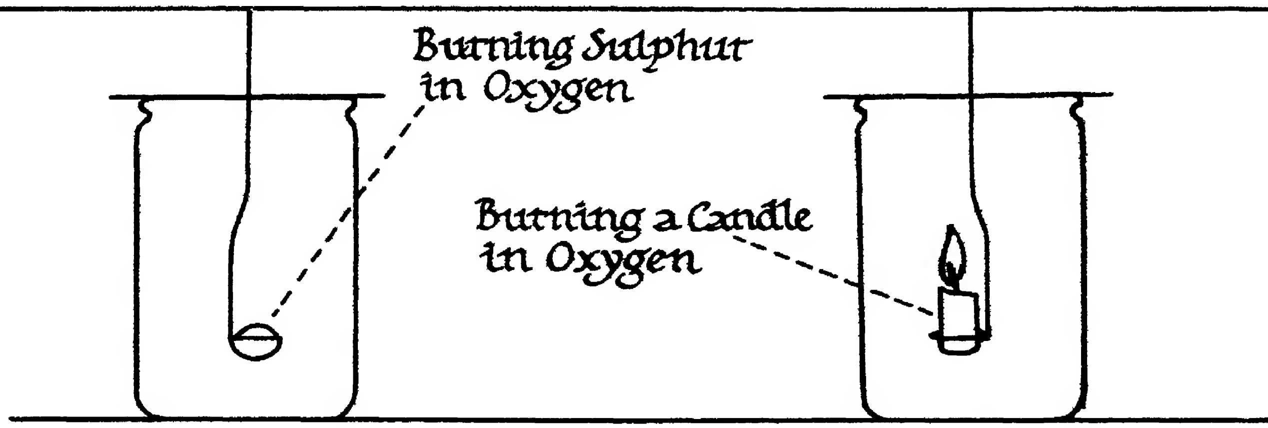
—IS THE SLOW BURNING OF IRON

Similar experiments can be made with carbon and powdered sulphur. For these you will need a deflagrating spoon, but you can probably make something like it if you have not got one. Light the sulphur or carbon in the spoon and when it is burning or glowing steadily in the air lower it into a fresh jar of oxygen. Note what happens, can you explain this? Try sprinkling in some hot iron filings.

In your record books make a table like the one shown here and fill in your own results.

When things burn in oxygen or in the air, they combine or unite with the oxygen to form other substances which we call oxides. Oxides contain the original elements as well as oxygen, even though in some cases the oxides are gases and are invisible.

The rusting of iron, as in your experiment last lesson, is a combining of iron with oxygen from the air. Indeed, we sometimes say that rusting is the slow burning of iron, so slow that there is no light or heat given out for us to see or feel.



SUBSTANCE	IN AIR	IN OXYGEN
Glowing splint	Glows	Bursts into flame
Sulphur	Faint blue flame	
Candle		
Carbon		

RUSH LIGHTS—

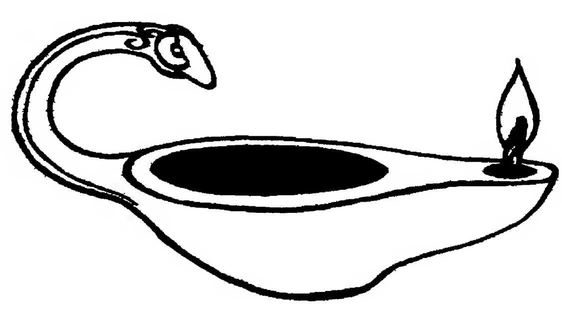
OUR ancestors depended upon the sun for heat and light, and we do not know exactly when the way of making fire and light was first discovered. One of the first substances that they burnt was wood. Things could be heated in this way, but the heat and the light given out could not be controlled, so there was some waste.

Later they almost certainly tried heating many different things to see if they would burn. In some parts of the world a thick oily liquid oozed from the earth, and the first man to burn this made light and heat from oil. Of course it was very crude oil, not a bit like the purified oils and petrols we know today. This impure oil would only burn after it had been heated, and had become a vapour.

The next step towards better and brighter lighting came when rushes or some twisted strands of material were soaked in this oil and lit. The wick was so fixed that it rested in the bottom of a vessel of oil, and when the top of the wick was lit the oil soaked up it and slowly burnt away. This crude oil was only found in some parts of the world, but alternatives were discovered, and we know that the Romans and Greeks used the oil pressed from olives, olive oil. In order to get a fairly good light from olive oil, it was necessary to use a wick.

Much later it was found that fats, for example mutton fat, when heated give off a vapour which burns in the same way as olive oil and

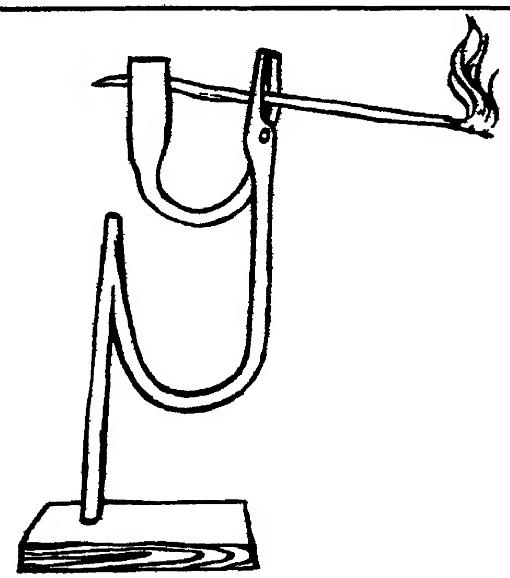
Our ancestors burnt wood



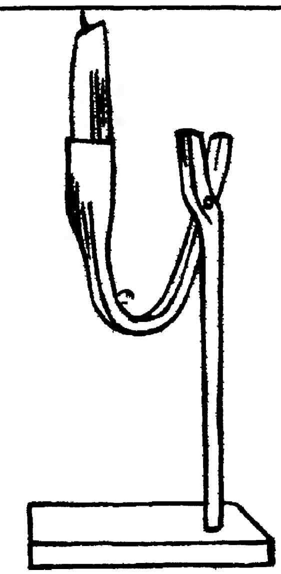
Roman Oil Lamp

the crude oil. The wick was allowed to set in a piece of solid fat and when lit a fairly good light was given out. This is how the first rush lights were made. Thin rushes were used instead of the wick, dipped into molten fat and left to set. These lights were somewhat smoky and spluttery. Various types of materials were tried for the wick, among them strands of hemp. The hemp was dipped, allowed to set and then re-dipped over and over again, until at last the first candle was made. The mutton fat was called tallow, hence the name tallow candles. But the modern candle is not nearly so smoky as the early ones. In those days carbon collected on the wick, and, as the candle burnt away, the flame got more and more smoky and the light duller until it was very poor. The wick was then cut off or trimmed and re-lit. Why is it that our modern candle does not have to be trimmed? It gives out a much better light than the early candle did, but even so provides a poor light by our standards today.

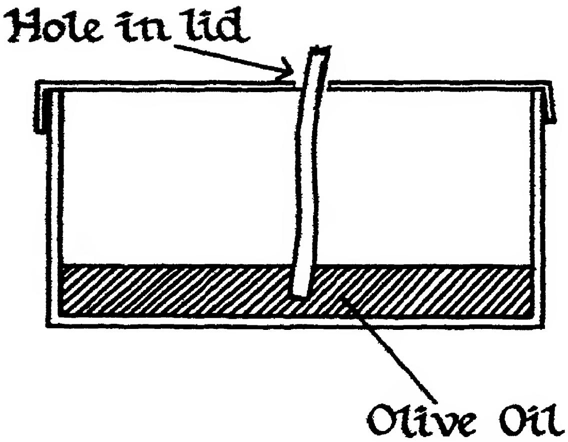
Gas lighting was introduced by William Murdoch at the beginning of the nineteenth century. First of all he used it for lighting his own house. Later, because of its advantages, it was used generally for both house and street lighting. The earliest gas burners were simply holes in the ends of the gas pipes, but a great improvement was brought about by the invention of the gas mantle.

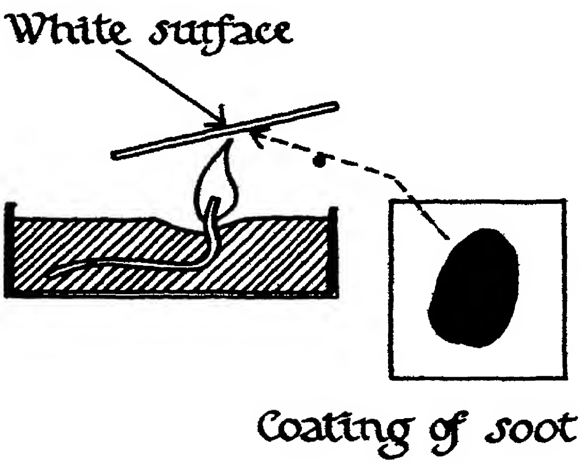


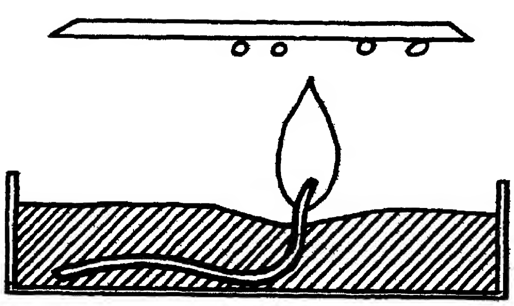
Rushlight in holder



Tallow dip in holder







Moisture condenses on a cold surface

YOU all know what happens when the end of a piece of blotting paper is dipped into ink, or the end of a towel is left hanging in some water. The ink and the water travel through the fibres of the material, and even when the blotting paper or the towel is held upright the liquid still spreads upwards. This rising of a liquid through a material is called capillarity. You have met this word before; do you remember it?

Put some olive oil into a small tin and try to light it on the surface. Does it burn? Now support a piece of lamp wick as shown, so that the oil can rise up the wick. Light the top. Does the oil on the wick burn? Olive oil as a liquid will not burn, but when it rises to the top of the wick the heat of a lighted match is enough to turn the very small amount of oil at the top of the wick to a vapour, and it is this vapour that burns. The heat of the flame then vaporises more oil as it rises and so a continuous flame burns. Liquids and solids do not burn with a flame. Only gases or vapours burn with a flame.

Now melt some pieces of candle wax in a small dish or basin. Into the molten wax dip some string and any other material that you think will make a suitable wick, and allow them to cool. When they are quite

—HAVE A WICK?

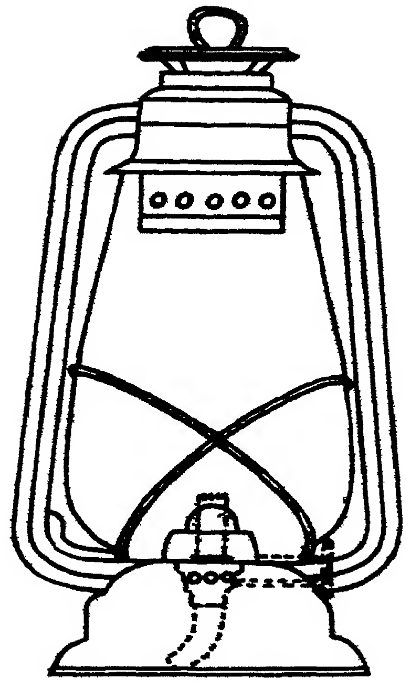
dry light them and compare the flames. Before the rest of the molten wax becomes too hard push a piece of string into it so that when it sets you have a home-made candle. Now put a light to your candle and hold a piece of white china over it. What happens? As your candle burns you may find that the wick has to be trimmed, if it is to continue burning properly.

Next time we shall talk more about the candle, but before then here is something for you to look up for yourselves. Can you find out how the wick of the modern candle is made, so that it burns away slowly and does not have to be trimmed?

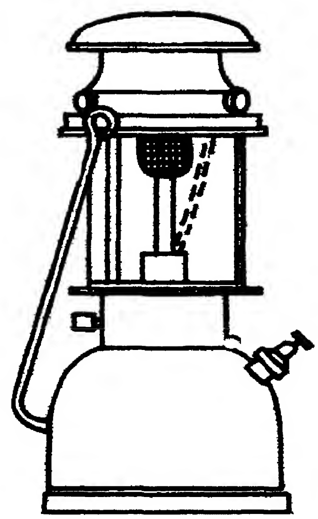
If you have a chance, examine any lamps that you can such as spirit lamps, hurricane lamps, pressure lamps, etc., and see whether you can find out how they work and are controlled. Why does a pressure lamp not need a wick.

Make a large chart showing how the ways of lighting have changed through the ages up to today. Either draw or trace the various types and look up the dates when they were first used, if you do not already know them.

Why is it dangerous to use petrol in a lamp designed to use paraffin as the fuel?



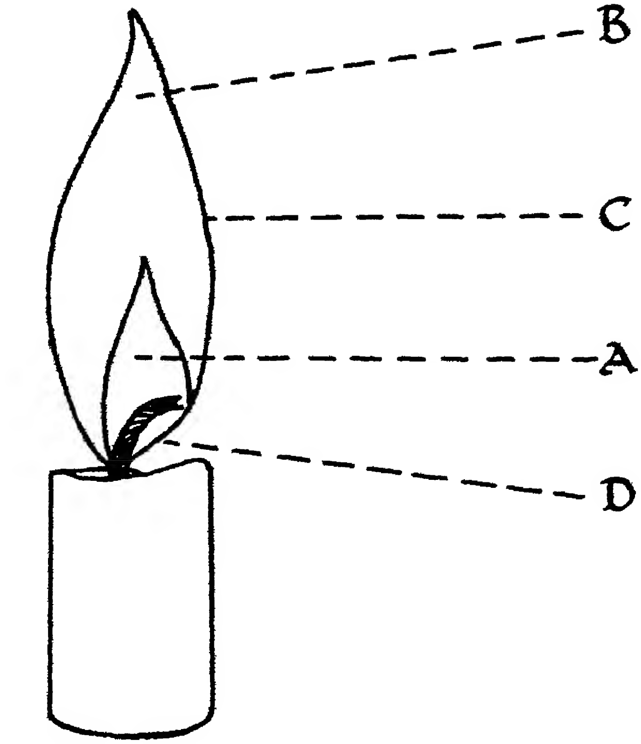
Section of a Hurricane lamp



Pressure lamp

Why does a pressure lamp not have a wick?

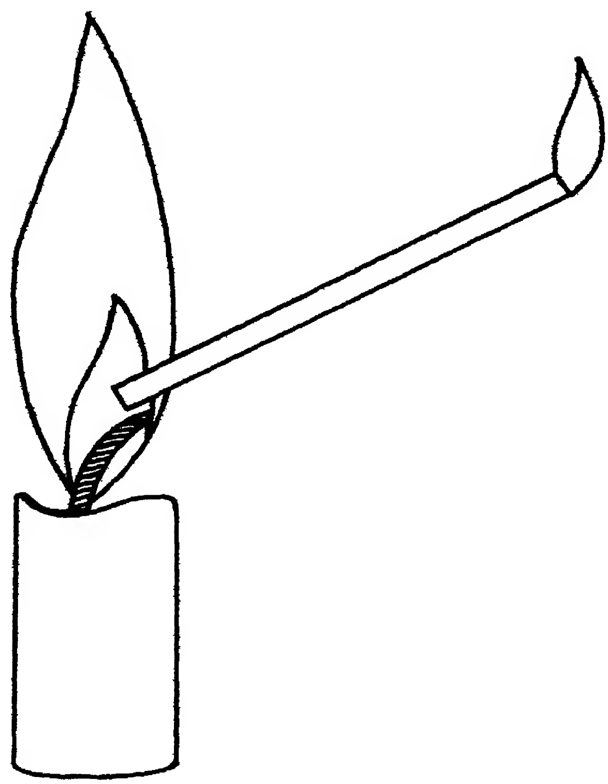
A CANDLE FLAME—



WHEN a candle wick is lit, the heat melts the wax, the molten wax flows up the wick where it is hot enough for some of the wax to turn into a vapour. This wax vapour combines with the oxygen in the air around, and heat and light are given out.

A candle is made up mainly of substances that contain only carbon and hydrogen. These substances are called hydrocarbons.

Light a candle and look carefully at the flame. At first you will see three parts or zones, but if you look more closely you ought to see a fourth. These zones are marked on the diagram. Describe these four zones in your record books.



Put the end of a short glass tube into the dark zone around the wick (Zone A) and hold a lighted match to the other end. Can you explain what you see?

Zone B is luminous; do you know the meaning of this word? Hold a cold plate or basin in this zone and watch the result. The cool surface becomes blackened with soot or carbon. In this part of the flame the particles of carbon are white hot. Because they are white hot this part of the flame is luminous.

Zones C and D are zones of complete combustion.

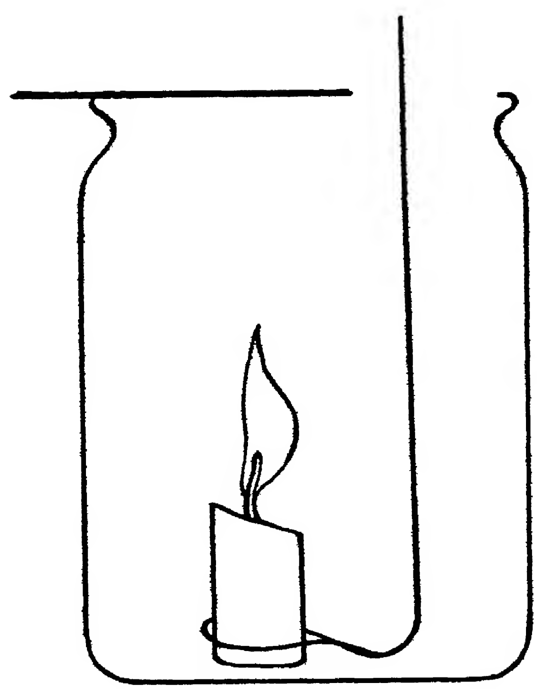
—HAS SEVERAL ZONES

Oxygen is needed for the candle wax to burn, and complete burning cannot take place inside the flame. Some burning takes place however, leaving some of the carbon unburnt. Around the outside of the flame there is a faintly luminous zone, and here the carbon burns away to form carbon dioxide, while the hydrogen in the hydrocarbons forms steam. This you cannot see, but if you hold a beaker of cold water above the flame, you may see something condensing on it. If enough of this liquid could be collected and tested it would be found to be water. It boils at the same temperature as water, and freezes at the same temperature; it is in fact water.

Do you remember the lime-water test for carbon dioxide? Use it now to show that carbon dioxide is formed when a candle burns. Lower a lighted candle into a gas jar or a clean dry jam jar. After a while the candle goes out. Why? Take out the candle and into the jar put a little lime-water. Shake it up and down being careful to keep the top of the jar covered. Do you think any carbon dioxide was formed? If so, where has it come from?

When the candle flame has gone out, do you think that there is any oxygen left in the jar?

Water is formed



Carbon Dioxide is formed

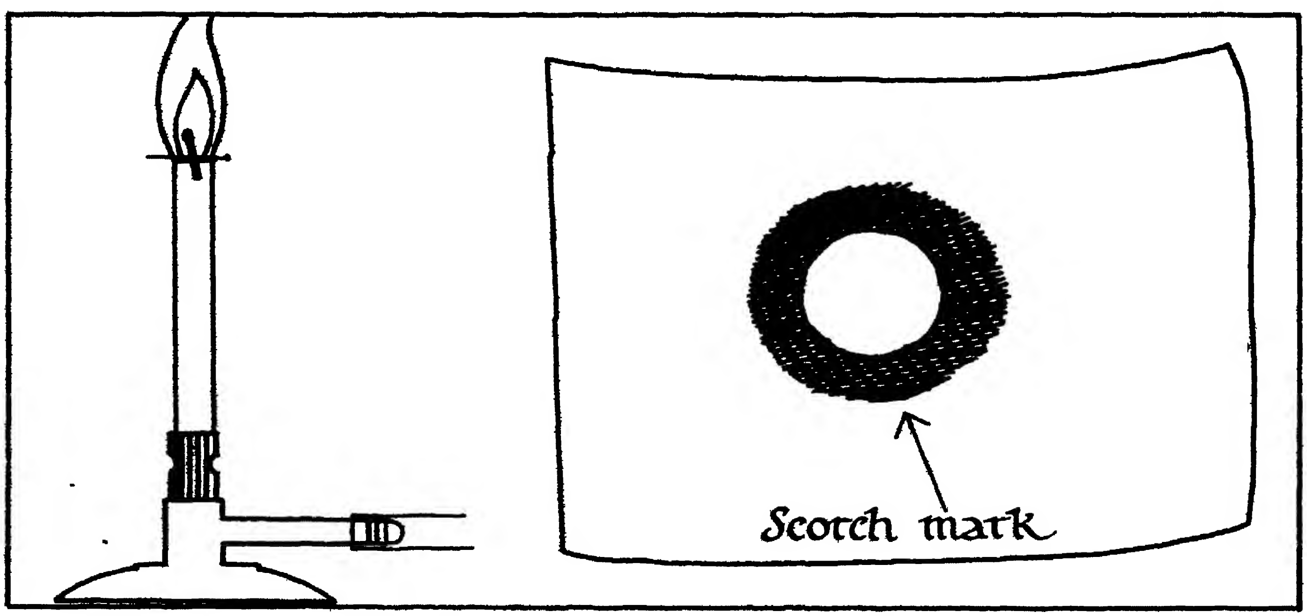
IN A GAS FLAME—

SO far we have only talked about flames that are luminous, that is to say, those that give out light as well as heat. Light is given out because the burning is not complete. To stop soot being formed air or oxygen must be well mixed with the fuel before the fuel is burnt. The Bunsen burner is an example of how this is done.

You will see that at the base of the burner there is an air hole. The size of this hole can be controlled by the circular collar. Light your bunsen burner and see what effect opening and closing the air hole has on the flame. Start with the air hole closed and slowly turn the collar so that more and more air can enter. Does the flame become more or less luminous?

Why does the air enter through the hole? Why does not the gas flow out through it? Unscrew the tube of your burner. On the base you will see a very narrow jet through which the gas flows. As it rushes up the tube, the gas draws in the air and take it up to the top of the tube with it. This very simple arrangement allows the gas to mix with the air before it reaches the top of the tube where it burns.

Screw back the tube on to the base of the burner. Now support an unstruck match inside the tube of the burner by means of a pin as shown in the diagram. Half open the air hole, turn on the gas and light it. The unstruck match does not light because the inside of the



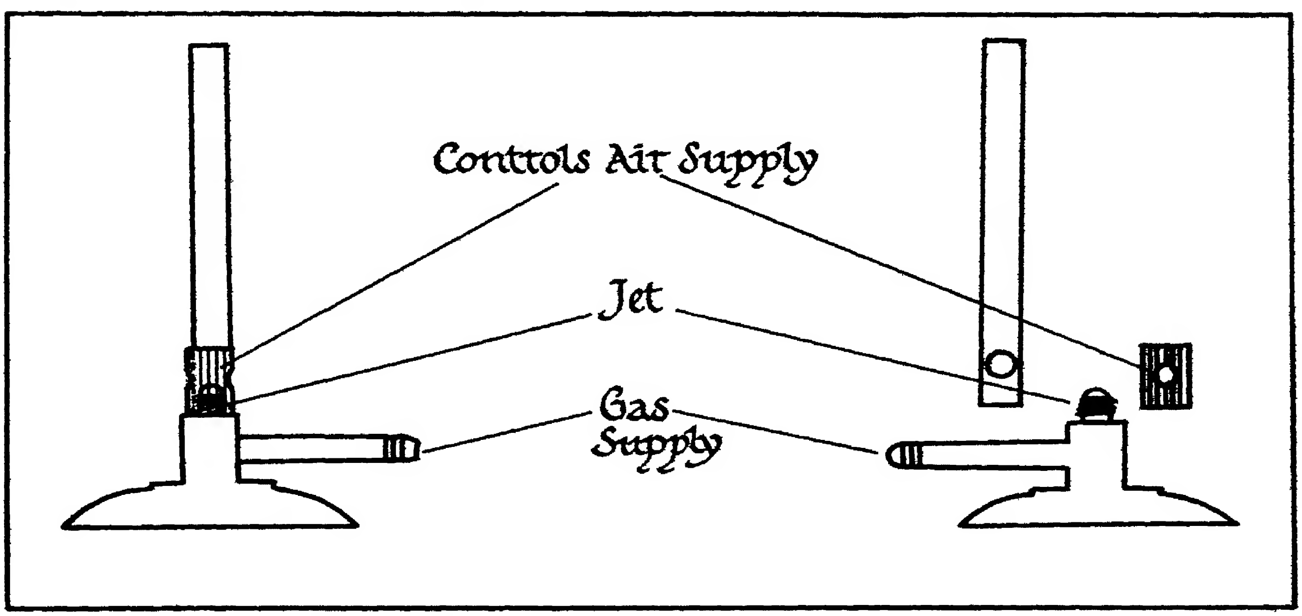
—THERE IS COLD UNBURNT GAS

flame is both hollow and cold. In the same way as in the candle experiment hold a short piece of glass tubing so that one end of it is in the flame near the match head. Hold a light at the other end of the glass tubing. What do you see? Can you explain this?

That the centre of the flame contains unburnt gas can be shown in another way. Very carefully press a sheet of white paper down on the flame for a second or two, and then remove it. What is on the paper?

Now close the air hole on your burner so that the flame becomes luminous. Hold a piece of broken china in the flame. Is there a deposit of soot? Open the air hole and try again. Why is there no soot formed this time? Leaving the air hole open, scrape a piece of carbon with a penknife near the air hole and watch the flame. The tiny particles of carbon are taken in by the rush of air and in the flame they become red or white hot and the flame becomes luminous. With the air hole open wide slowly turn down the supply of gas. At a certain point the flame will run down the barrel of the burner and burn at the jet. This is called "striking back" or "burning back".

Is there any air control for the burners of a gas oven? When a bunsen flame strikes back, why does the flame stop at the jet instead of travelling down the tube or pipe to the main?

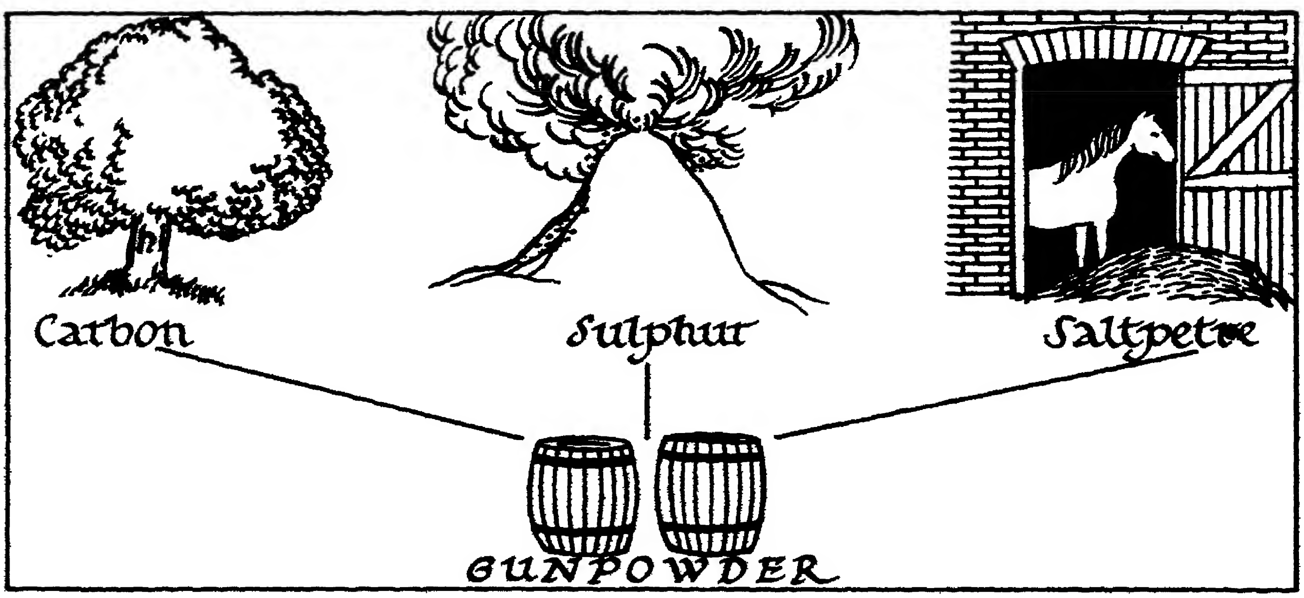


SALTPETRE URGENTLY NEEDED

WE have seen that when sulphur and carbon burn in air or oxygen two gases, sulphur dioxide and carbon dioxide, are formed. These gases take up much more room than the original solids. When this burning takes place in an open jar or vessel this fact does not matter; but what happens if the two substances are burnt very quickly in a small closed space?

So that sulphur and carbon may become sulphur dioxide and carbon dioxide, oxygen is required in large quantities, otherwise the burning will not be complete. Since oxygen is a gas it would be difficult to get enough of it into a small container for the needs of the sulphur and carbon. The oxygen must be in some other form which is not bulky. This is where the oxygen in saltpetre is useful. When saltpetre is heated oxygen is given off. This oxygen can be used to allow the burning of sulphur and carbon so that they form large volumes of gases. Therefore, when sulphur, carbon and saltpetre are mixed together and set alight, the burning is complete and very vigorous; large volumes of gases are set free quickly and an explosion occurs. For many years saltpetre was one of the most important ingredients of gunpowder.

During the seventeenth century gunpowder was used more and more in warfare, and the demand for it led men to study it. There were three main ingredients: charcoal, sulphur and saltpetre. There was not much difficulty in getting the charcoal from wood, and sulphur



SPECIAL OFFICERS APPOINTED!

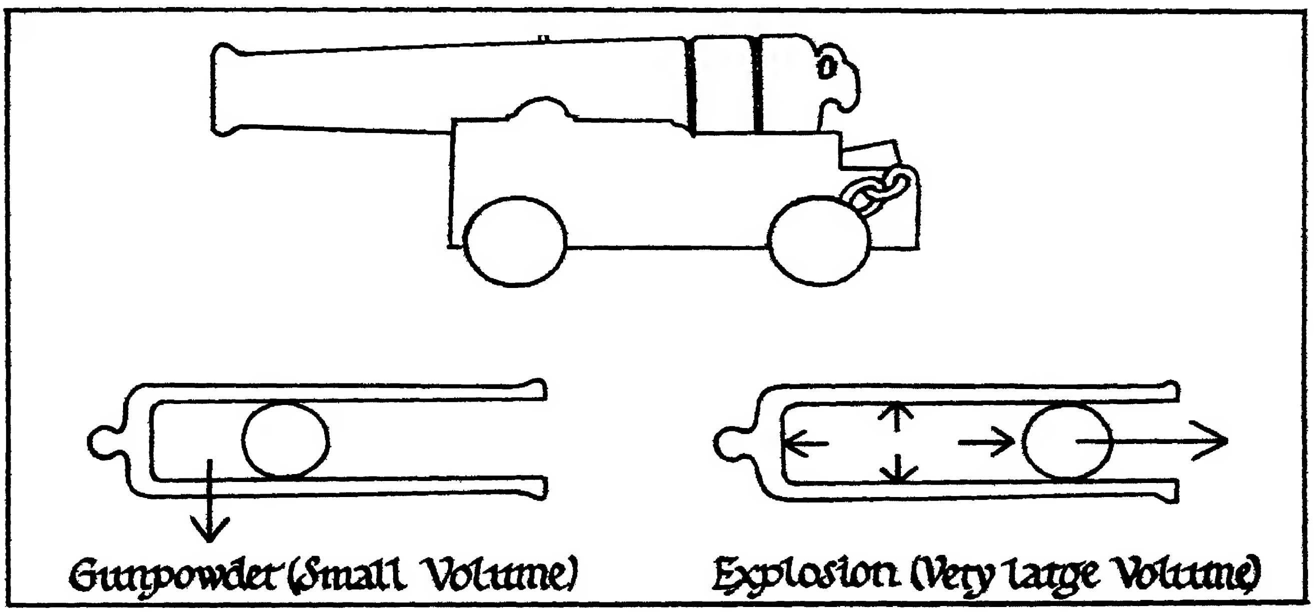
was obtained mainly from the volcanic areas in Southern Europe. But it was much more difficult to get the saltpetre. In India and China forms of gunpowder were known much earlier than they were in England, and in these countries there were natural deposits of substances called nitrates, among them saltpetre. These substances were to be found in manure heaps, and because these countries went for long periods without rain which would have washed away the nitrates, the deposits accumulated.

In Europe there were very few places where nitrates could accumulate naturally, so a search was made elsewhere, for example in dry and sheltered places such as stables and cellars.

Because the manufacture of gunpowder was so important, especially in time of war, it became the subject of Royal Decrees. In France special officers were appointed to look for, and to extract saltpetre. They investigated everything; no buildings were pulled down until they had given their permission, and then only if there was no saltpetre to be obtained from them.

This need for saltpetre led to two developments: first to the way of making it artificially, secondly an investigation of the ways in which plants obtain their food.

Later it was found that gunpowder burns even more rapidly when detonated, than when started with a flame.



THE DAVY LAMP BROUGHT—

METHANE is a gas that occurs in coal-mines, being probably trapped there at the time decaying vegetable matter was being changed into coal. Miners call this gas "firedamp". If it is mixed with air and comes into contact with a flame, it will explode. Apart from the explosion there is another danger, that of poisoning by the carbon monoxide, formed when firedamp burns in a limited amount of air, as happens in a coal-mine. This poisonous gas, carbon monoxide, is called "after-damp" by the miners.

Firedamp was a serious problem in the mines. Miners must have a light to work by, and a naked flame was all they had in days gone by. How was the problem overcome?

Look at the diagrams.

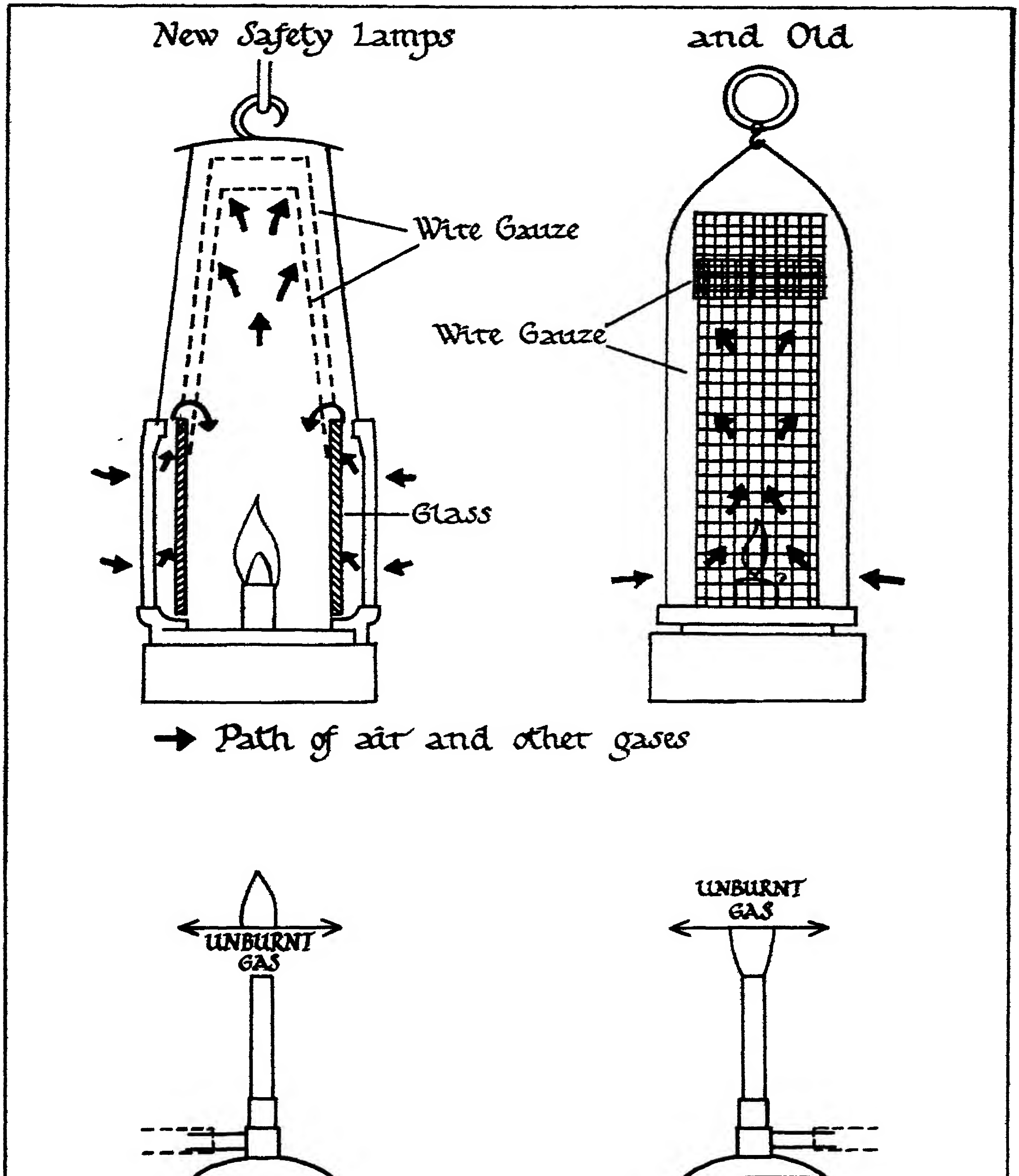
One shows the earlier kind of Davy safety lamp, the other is a later type, but both use the same principle. What improvements have been made? The flame is surrounded by a wire gauze. Firedamp needs quite a high temperature before it can catch fire. A miner, using a Davy lamp, would be quite safe in an area containing the dangerous mixture of firedamp and air. The inflammable gases could pass inside the lamp and burn, but the heat is conducted away from the flame so quickly by the fine wire gauze, which even when it gets really hot, is still at too low a temperature to light the explosive mixture of gases outside.

Sir Humphry Davy invented this lamp solely to save the lives of miners, but it had another advantage as well. It allowed dangerous mines to be worked more safely, without the fear of loss of life from explosion and gas poisoning.

Here is an experiment that will show you the principle of the lamp. Hold a piece of copper gauze in a pair of tongs and lower it slowly into a bunsen flame. The flame does not appear above the gauze, although there is unburnt gas there as you can show by holding a lighted taper above the gauze.

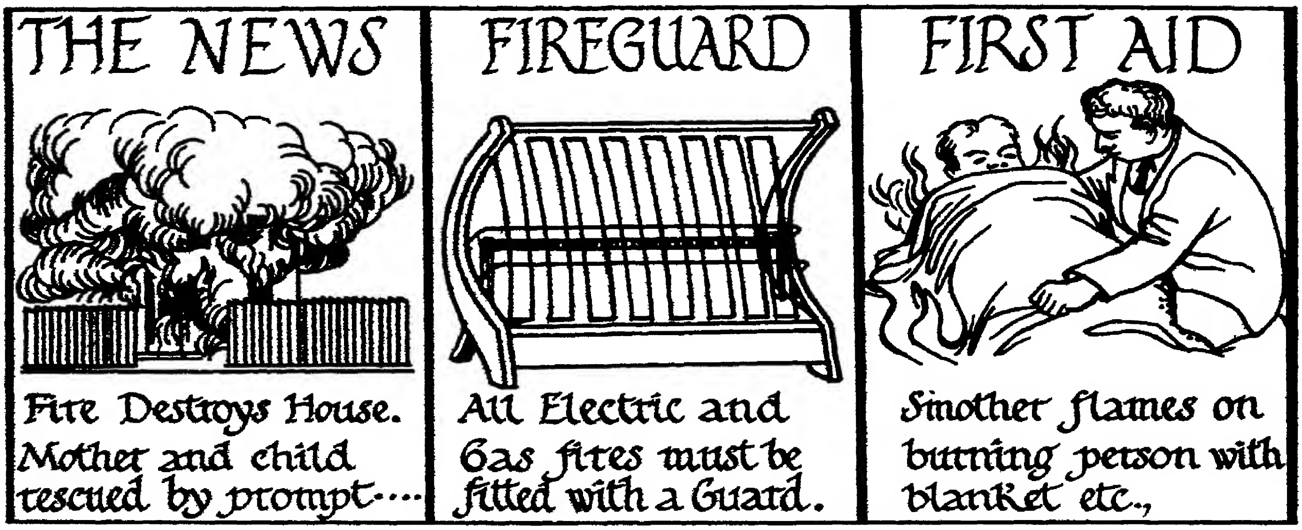
Now hold the gauze over an unlit bunsen and turn on the gas. When the gas above the gauze is lit the flame does not travel through the gauze. In both of these experiments the copper gauze conducts the heat of the flame away so that the gas on the other side of the gauze is kept below its "ignition temperature", and therefore it does not light, or ignite.

—SAFETY TO MINERS



The arrows show heat being conducted away by the gauze

KEEP YOUR HEAD IN A FIRE



FOR every fire of which we read in the newspapers, there are dozens of smaller fires that are safely dealt with by sensible people. Small fires can be prevented from spreading by prompt and correct action.

If a small thing catches fire, it is best to remove it to a place where it can safely burn itself out. For instance if a pan of boiling fat catches fire probably the best thing to do is to remove it from the stove and put it outside in the garden, away from all buildings, until it has burnt out.

Unguarded fires, whether electric, gas or coal can be the cause of much suffering by burns, especially to children. All electric and gas fires sold today must by law be fitted with a dress guard, but despite this precaution there are still many accidents where clothing catches alight from a fire. When this happens the flames should be smothered quickly with a blanket or rug; the quicker the patient is entirely wrapped up, and air is excluded from the burning clothing, the better. The flames will be extinguished in the same way as a bonfire can be put out by smothering it with earth and so excluding the air.

Another way to put out a fire is to reduce the temperature of the burning material. Of course anything very small can be put out by blowing on it; this cools it down. If a pile of wood and wood shavings catches fire, is it sensible to run quickly for a bucket of water? But to prevent fire altogether is best. Fire precaution regulations are laid down. All big buildings must have buckets of sand, water, and chemical

KNOW YOUR FIRE DRILL

fire extinguishers. All three are necessary to deal with the different types of fires. Water must never be put on burning oil. It must be blanketed with sand, or put out with a chemical extinguisher. Where new forests are being planted special lanes are left between the trees so that if a fire breaks out it does not easily spread through the whole forest. Here are some questions, can you answer them?

1. How would you set about putting out a fire on a heath or scrubland?
2. If a lighted paraffin stove was knocked over and a carpet began to burn what would you do? Should you open the door or shut it?
3. If you were trapped in a room full of smoke should you sit in a chair or lie on the floor?
4. How do you call the Fire Brigade on the telephone?
5. Do you know your School Fire Drill?
6. What types of fire extinguishers have you at school? Where are they kept and how do they work?
7. What other tasks are fire brigades called upon to do apart from fire fighting?
8. What are the main causes of fires?

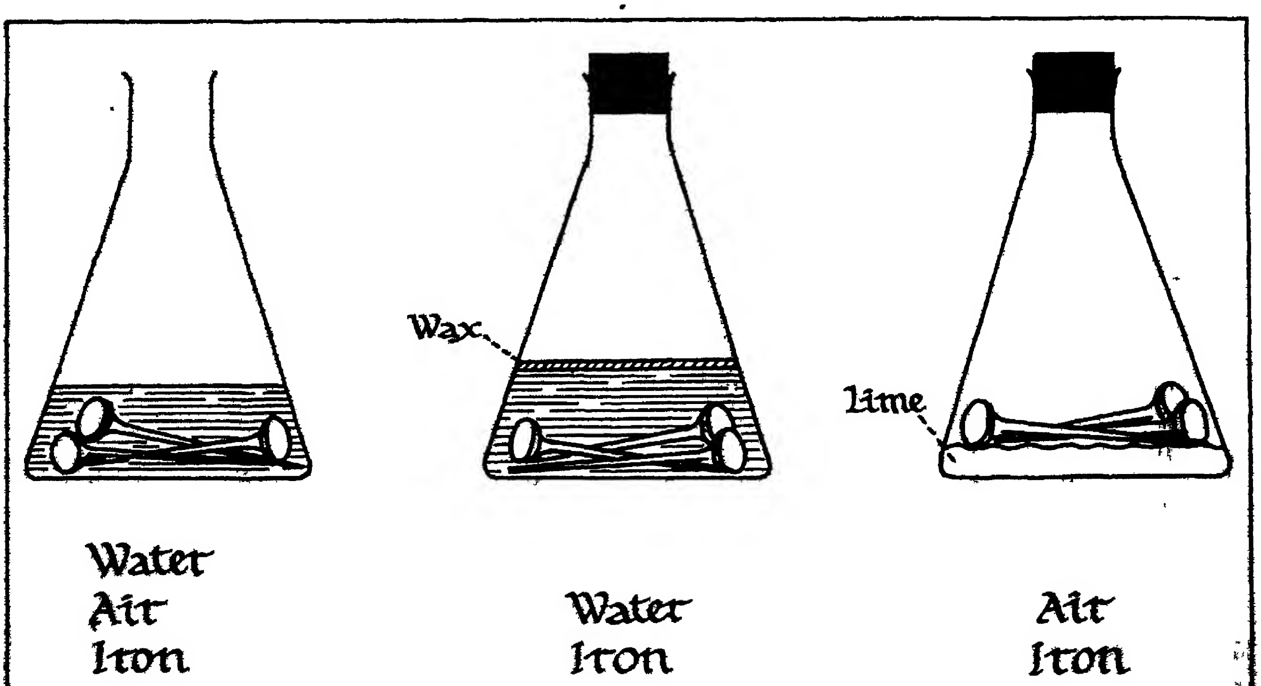
Make a collection of newpaper cuttings about fires, and their causes. Check your answers to the above questions and then make a chart in your record books showing the causes and how to deal with various types of fires.

THE RUSTING OF IRON

ALTHOUGH iron is used in practically every large industry and millions of tons of iron are used every year in various forms, it has one great disadvantage. All articles made of iron and certain types of steel will rust if they are not specially treated. Many articles such as knives, spades, shovels, iron railings, all rust if they are not protected, or if the protective coating on them is allowed to deteriorate.

What conditions are necessary for iron to rust? Why does a garden fork rust? Working with small quantities we will try to answer these questions now.

You will need three small flasks or jars, and some nails about two inches long. Polish the nails until they are bright. Put two or three of them into one of the flasks with a little water, and leave the flask uncorked. Into the second flask put some water and boil it until all the air is boiled from it, and the space above is filled with steam. Quickly drop in a few nails and put some molten wax or oil on the water. Cork the flask and seal it with some more molten wax. This will stop any air entering the flask. Into the third flask put the rest of the nails with some lime and cork it up. We use lime because it attracts water, and will keep the air in the flask dry. Put the three flasks away; inspect them each day. Rust will begin to



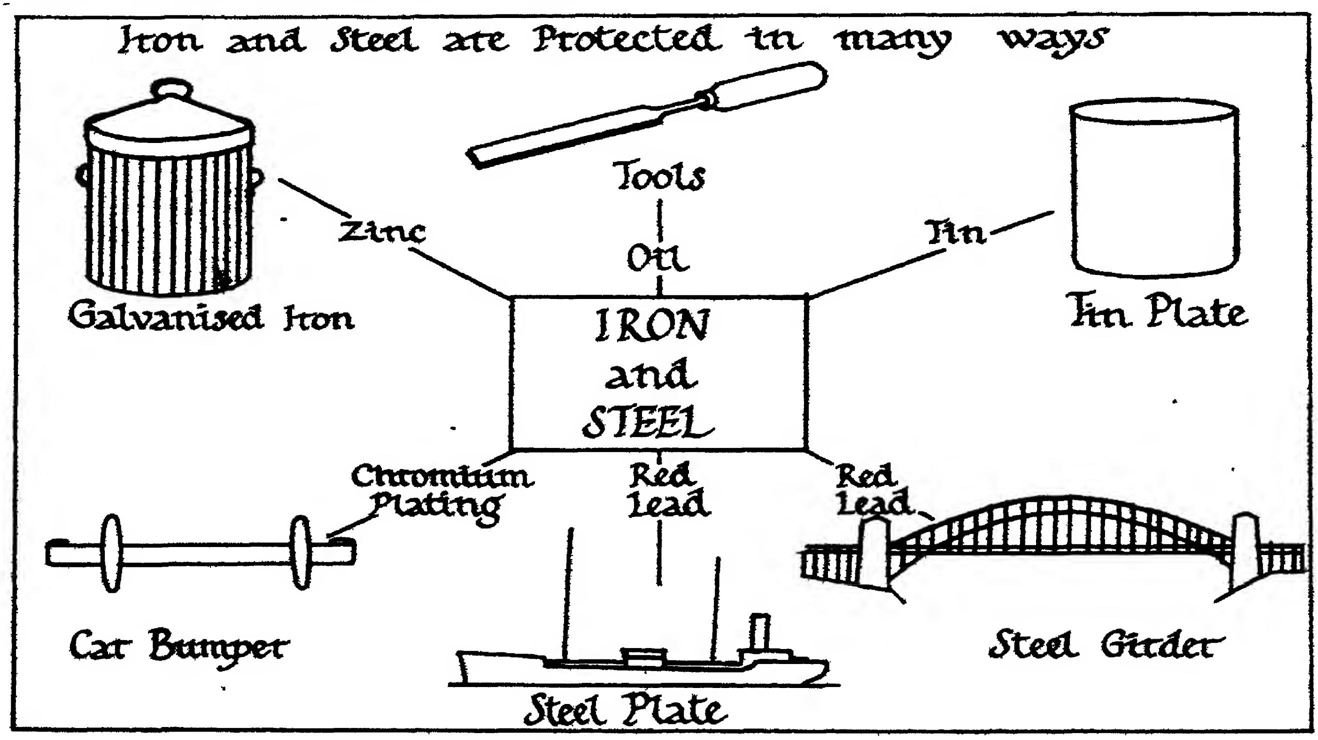
THE WASTING OF A NATIONAL ASSET

appear on some of the nails, but not on all of them. From your observations can you now say what conditions are necessary for iron to rust?

How can rusting be prevented in industry and in the home? There are several ways of keeping the iron surfaces free from air and moisture, and the actual method used will depend on the article and what it is used for. Oil and grease on tools will prevent the rusting of the steel of which they are made. It is not possible to coat the metal of tools with anything harder or more permanent if they are to work efficiently. Painting with red lead, aluminium or zinc primers will protect surfaces, especially large areas that are exposed to wind and rain, for example those found in ships.

Iron articles are sometimes plated with tin or zinc. Those plated with zinc are said to be "galvanised". The advantage of galvanised iron is that the coating of zinc protects the iron, for when the article becomes damp and corroding takes place the iron is not affected quickly, as the zinc "wears" away first. Dustbins and buckets are examples of galvanised articles.

If a more pleasing finish is required articles are often plated with nickel or chromium, two metals that keep their lustre under conditions which cause iron alone to rust.



CLEAN HEALTHY AIR WILL COST MONEY

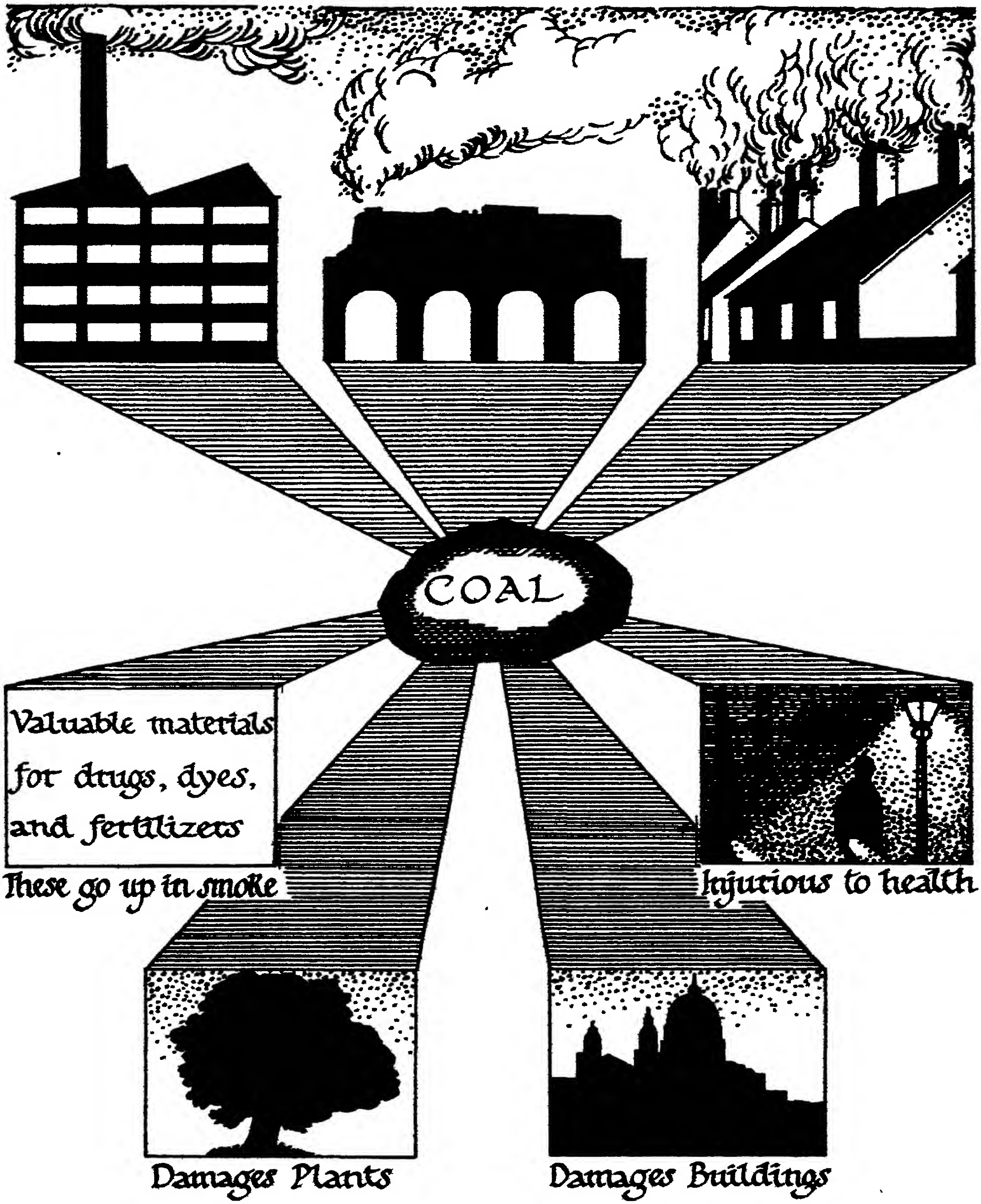
SMOKE, grit and dust are continually being thrown into the air, but it is only recently that this fact has been considered a national problem. Matters are made very much worse during damp and foggy weather when there is little or no wind to clear the air. This unpleasant and dangerous mixture of fog and smoke is known as "Smog".

The domestic fire is the biggest single smoke producer, closely followed by factories and railways. An ordinary household coal fire has two disadvantages. First, it produces twice as much smoke from, say, a ton of coal as does the factory fire. Secondly, it has the disadvantage from which railway engines also suffer—that smoke is sent out from low chimneys and has less chance of dispersing than has smoke from tall factory chimneys. Millions of pounds a year are wasted because damage is caused by smoke and grime, and in addition the valuable substances that could be extracted from coal are lost. A gas, sulphur dioxide, is also sent into the air. This, with rain, forms an acid which causes an immense amount of damage to stonework.

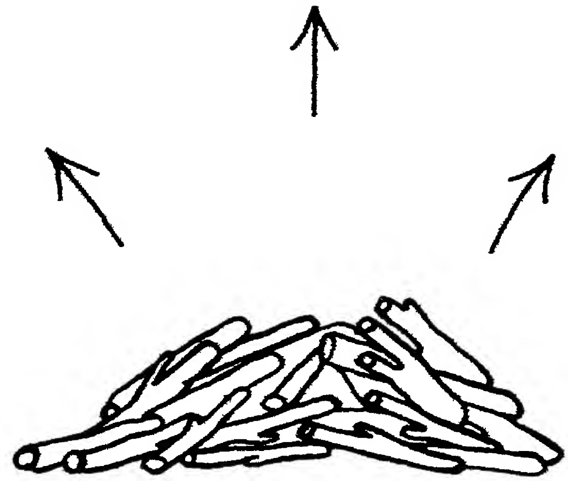
Several very small areas in the country have been made into "smokeless zones". The fuels used in them must either be smokeless or must be used in such a way that no smoke is thrown into the air. The ideal would be to make the whole country a smokeless zone, but there are difficulties. There are over ten million coal-burning grates in use, and for them to burn coke or anthracite, two smokeless fuels, it would be necessary to have them changed at vast expense. More coke burning fires mean more demands on the supply of coke and a possible shortage. A better quality coke will burn in the existing grates, but it would cost more. Many new housing estates are planned so that they use only smokeless sources of heat such as coke, gas and electricity.

Railways are changing over to electric and diesel power, so that in time the fog over shunting yards and large stations will disappear.

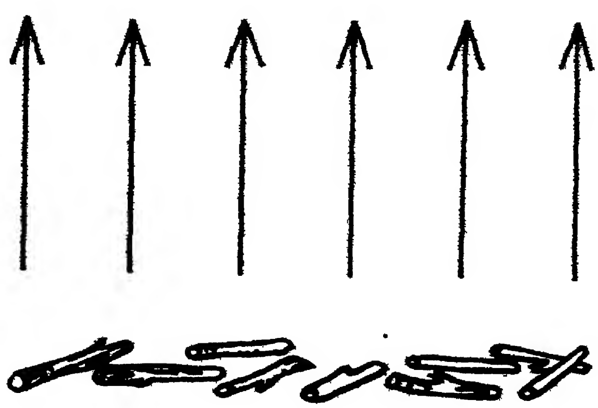
Improvements to make fuel burn more efficiently are being made in industrial areas. Special dust extractors are used. Mechanical stoking, improved plant design, and more skilled attention, all help to tackle this menace. Some industries, particularly the pottery industry, are going over to electric firing. If these improvements could be adopted throughout the country, the damage to health, buildings and plant life could be banished for ever.


COAL
Valuable materials
for drugs, dyes,
and fertilizers
These go up in smoke
Injurious to health
Damages Plants
Damages Buildings

FIRES THAT START—



Small Surface Area. from which heat is lost slowly



Large Surface Area. from which heat is lost rapidly

A FIRE, providing it is a certain size, will burn away quite brightly, but if it is allowed to get too low it goes out, although there may be unburnt fuel there. In this case, heat is lost rapidly so that the whole fire goes out. A well-built fire will keep its heat and not lose it too rapidly by radiation.

Those among you who are scouts and guides should already know the correct way to build a fire. The rest of you have probably helped to build bonfires in your own gardens. Perhaps your school has a school garden or allotment. What happens to rubbish that cannot be rotted down for compost? Is it burnt? If so watch carefully next time how the bonfire is made of this rubbish.

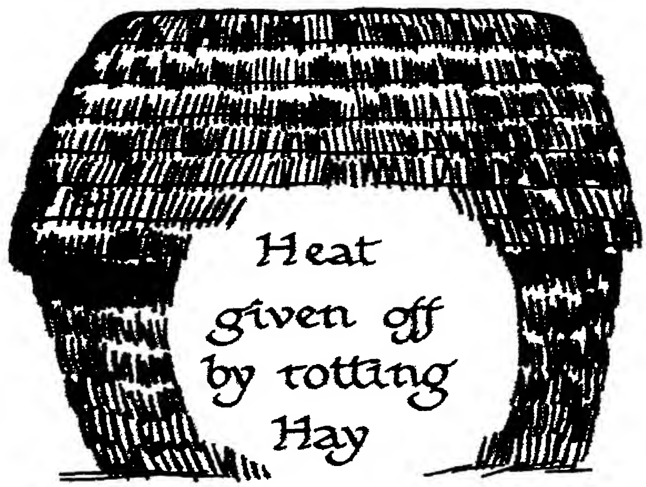
When we light a fire we do not light it on the outside only. By using paper and wood, or a gas poker we make certain that the fire is started in the centre. From here the heat spreads out, heating the rest of the fuel. But on the other hand when we want to put out a fire we spread out the embers, so that the hot surface is made as large as possible. Heat is then lost by radiation very quickly and the fire goes out.

In the country a haystack sometimes catches fire most mysteriously. This type of fire starts in the

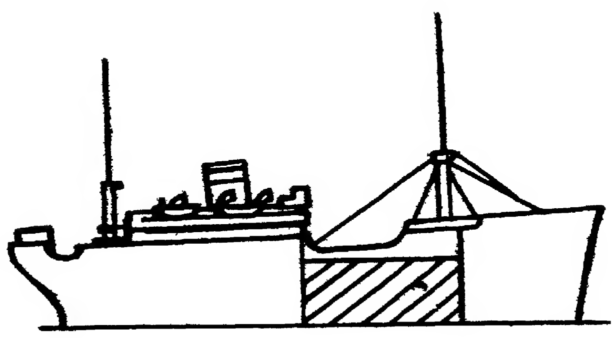
middle of the stack and burns outwards. Usually there is a reason for this. Perhaps the hay was not perfectly dry when it was stacked, or possibly the thatching did not keep out all the rain. Then the hay inside the stack, because it is or has become damp, begins to rot. When this happens heat is given off and because the hay is a very good insulator the heat is not lost to the outside very quickly. The temperature inside the stack rises higher and higher until suddenly the haystack bursts into flame. When burning, or combustion as it is called, begins by itself in this way without any help from the outside it is called "spontaneous combustion".

There are other examples of spontaneous combustion. Sometimes piles of waste rags catch afire in this way, while fires have occurred at sea in the holds of vessels carrying damp cargoes.

Although the temperature in the haystack or in the damp cargo in a ship may rise above the ignition temperature of the material, combustion will not take place until there is contact with the air, so that oxygen is present to support the combustion. By this time, quite a large amount of the material is above its ignition temperature so that when combustion does start it is extremely vigorous.



Hay is a very good insulator. The heat is Kept in.



Damp cargo begins to rot. Heat is retained. The temperature rises until the cargo bursts into flame.

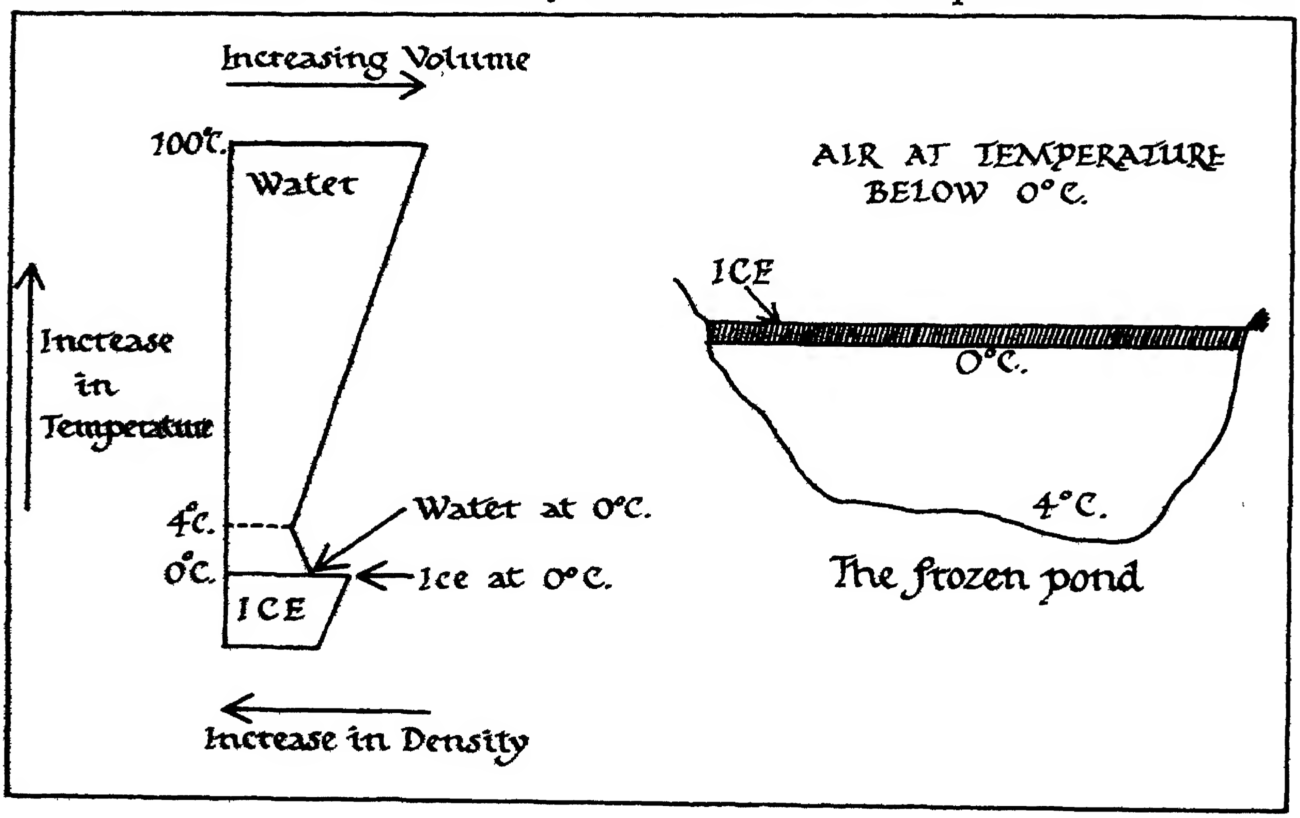
THE ODD BEHAVIOUR OF WATER

HEAT is transmitted in three ways, by conduction, convection and radiation. All materials will conduct heat, but some much better than others. Poor conductors, for example wood and asbestos, are usually called insulators. Metals such as copper and silver are good conductors of heat.

We have seen that most substances expand when they are heated and contract when they are cooled. But there is one very important exception. It is water. Have you ever thought why ponds, except very shallow ones, never freeze solid? Let us make two experiments.

First tie a small piece of ice to a piece of lead and sink it in a tube of cold water. Gently heat the water at the top of the tube until it boils. Even after the water has been boiling for some time the ice remains unmelted at the bottom of the tube, for water is a bad conductor of heat. But what happens if the ice is floating on the top of the water and the tube is heated at the bottom?

When water is cooled from room temperature it contracts and becomes denser. The density increases as the temperature falls until



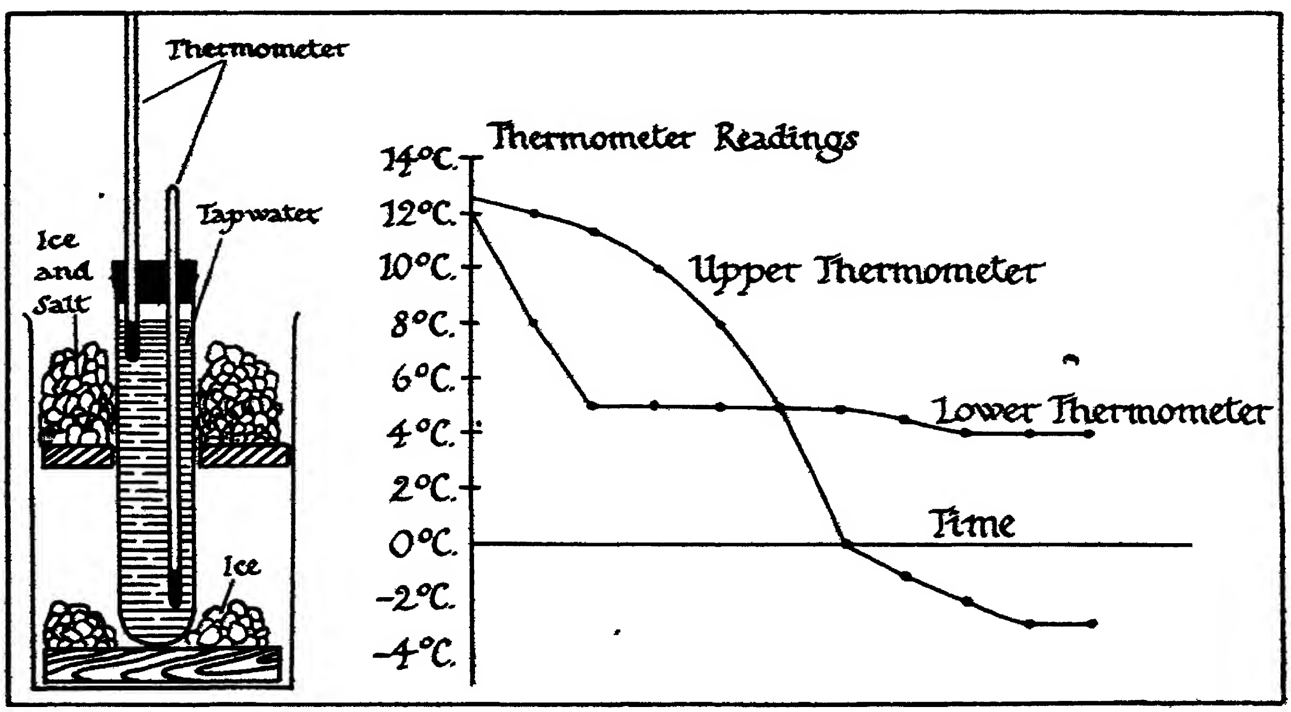
The frozen pond

it reaches 4° C., but if the water is cooled still further then it begins to expand and becomes less dense. So if we have water at a temperature of 4° C. it will expand if we either heat or cool it. The diagram shows you how the density of water changes with the temperature. Can you "interpret" the diagram?

Look at the diagram of the pond. Can you now say why the pond does not freeze solid? Because the maximum density of water is above its freezing point, water does not sink to the bottom as it gets near to its freezing point. In this way, by this oddity of cooling water, life in ponds and rivers is enabled to continue.

For our second experiment, we need the apparatus that is shown in the diagram. A tube is filled with tap water and rests on a block of wood. The upper half of the tube is surrounded by a mixture of ice and salt supported on a wood disc. Two thermometers are held in the cork as shown and the whole is put into a large glass jar. A few pieces of ice are put on the wood block at the bottom to cool the air in the bottom of the jar. The temperature readings on the two thermometers are plotted as shown. Can you read and explain the graph?

Antimony and some of its alloys have the property of expanding when they solidify. Can you find any uses to which this property is put?

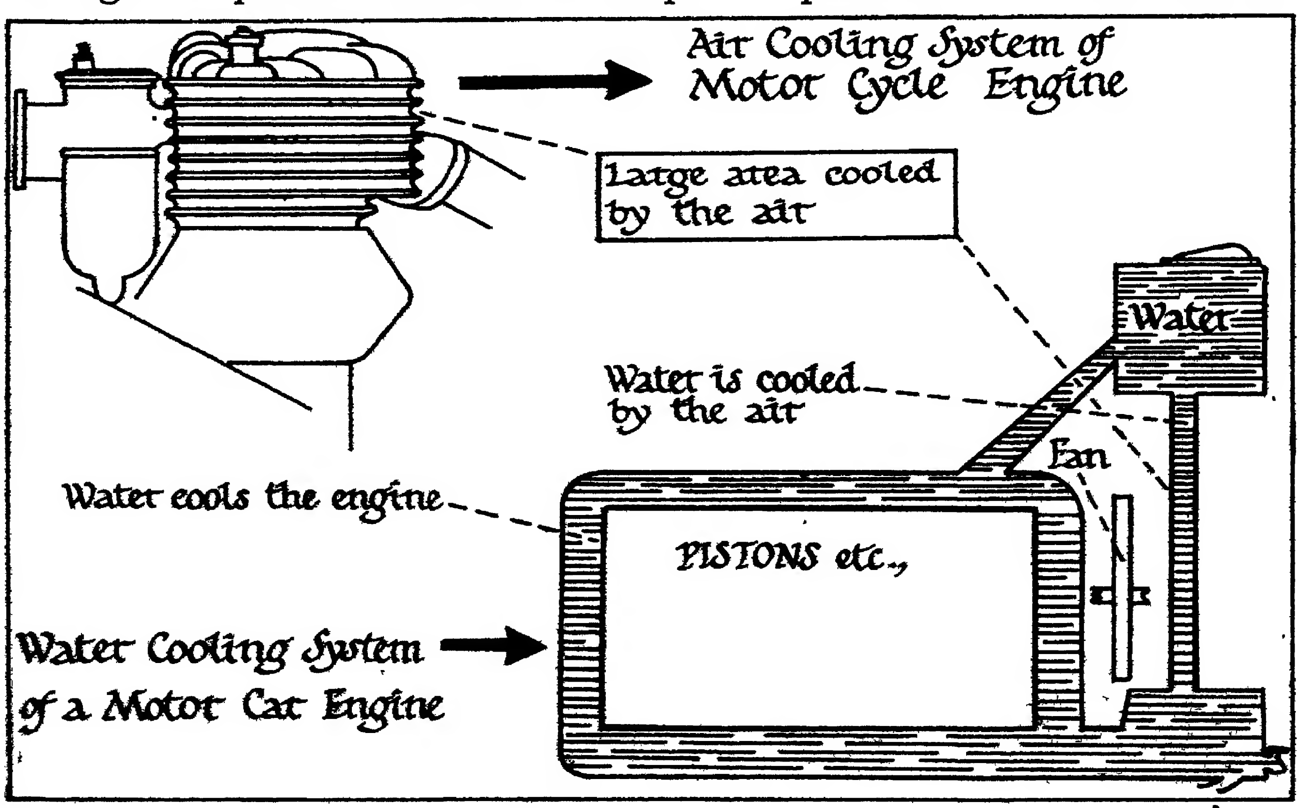


COOLING BY AIR AND WATER

WE do not always want to retain heat. Sometimes we want to get rid of it as soon as possible. Our next diagram shows the "finning" on a motor-cycle engine, and the other the water jacket that surrounds a motor-car engine. Copy these into your record books, and in your own words write a description of how they both work.

Water can evaporate at any temperature, but it needs a certain amount of heat to do so. This heat can come from anywhere; from the container and surroundings; from the air, from the water itself. As the water takes this heat, so the temperature of the sources of the heat falls. Thus, if a saucer of water is left to evaporate, the water slowly changes into vapour, and the temperature of the saucer and the remaining water falls. You may have experienced this yourself if you have ever waded into a shallow exposed pool or pond. Although the surrounding air may have been very warm, the water may feel icy-cold.

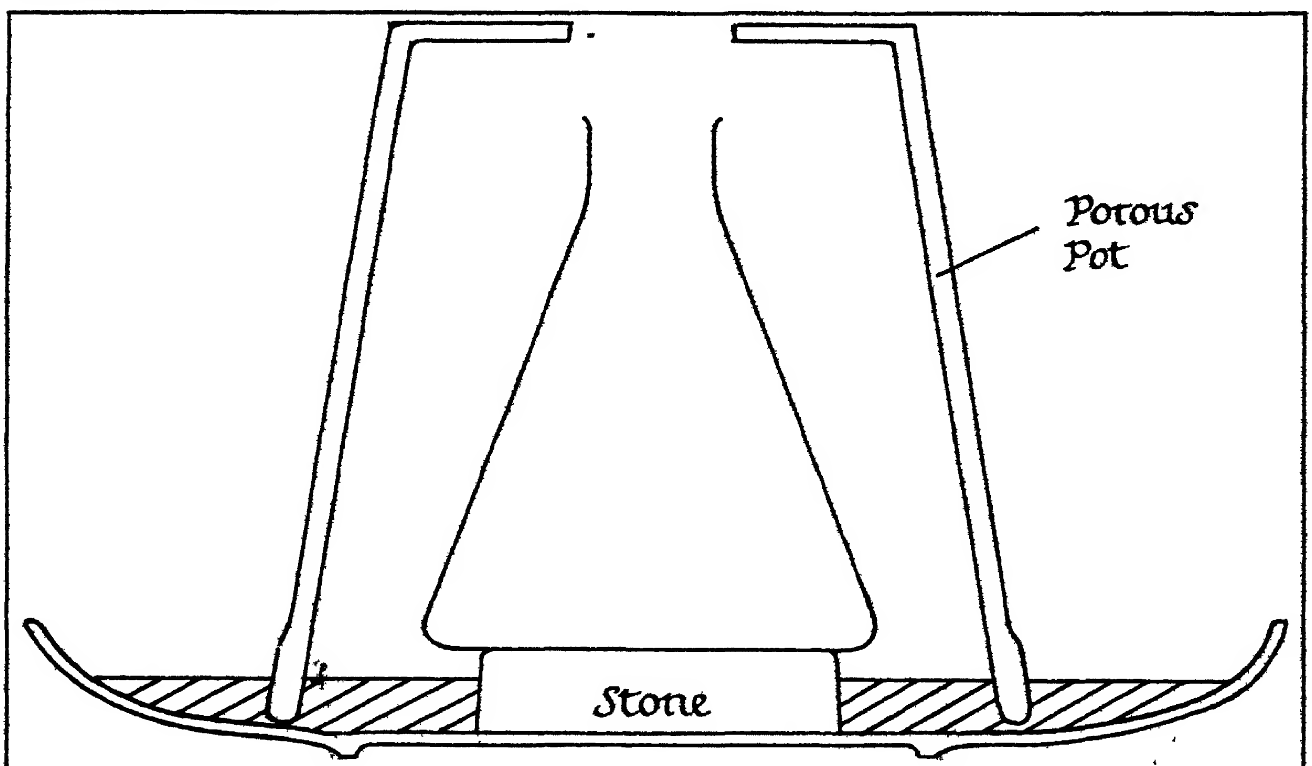
In some hot countries this cooling by evaporation is made use of to keep drinking water cold. This water is stored in large porous pots, and put where there is a moving current of air. The water seeping through the porous material of the pot evaporates. The heat that is



COOLING BY EVAPORATION

needed for this is taken from the pot, so that the remaining water is kept very cool. The simple butter and milk coolers that we use in this country make use of the same idea. In hot weather butter may become soft, may even melt and be unpleasant to eat. Both butter and milk coolers are made of unglazed earthenware. The cooler is soaked in water and then stood over the butter or milk, so that the bottom of the cooler is resting in a small trough of water. The water evaporates by taking heat from its surroundings which are then cooled, and so the butter or the milk inside stay cool.

Fill three small bottles or flasks with water. Put one aside in a warm place with a thermometer in it. Using a clean flowerpot make a cooler as shown and put it over the second bottle of water and place it next to the first one. Stand the third in a shallow bowl of water. Drape a clean cloth over it so that the ends of the cloth are in the bowl of water. Put this with the other two. At the start the temperature should be the same in all three bottles. At regular intervals take the temperature readings. Can you account for the differences in the readings taken?



HOW THE HOT—

WHEN water that is above 4°C. is warmed it expands and, as a result, becomes lighter. The colder and denser water from the upper layers sinks and forces the warm water upwards. You have seen this take place in a beaker of water, a crystal of permanganate being used to indicate the movement of the water. Another way of showing this fact is by means of the piece of apparatus shown in the diagram. Again, in the flask there is a crystal of permanganate to show the movement of the water. What will you expect to see when the flask is warmed gently? Now warm the flask and see if you were right.

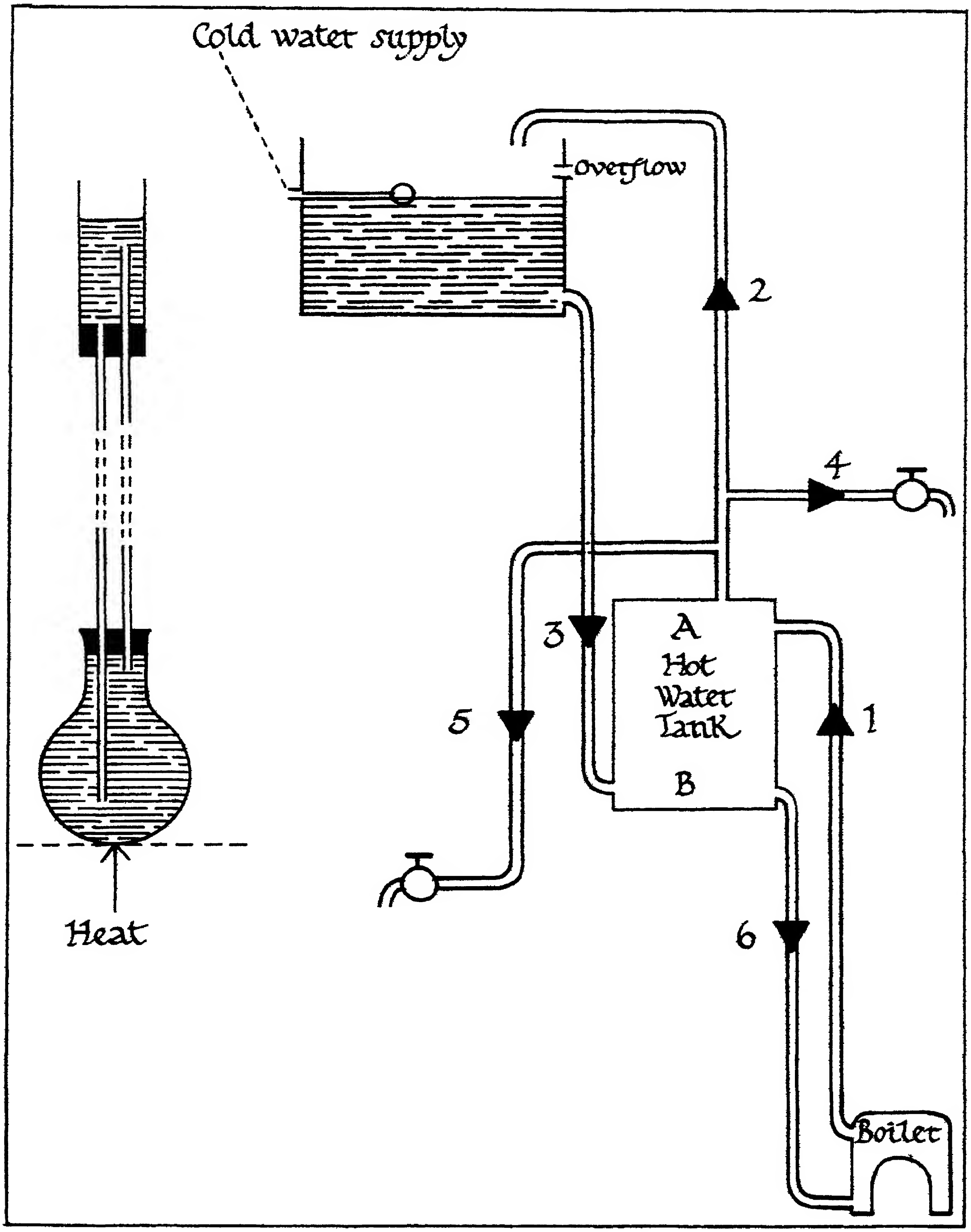
This ascent of hot water and descent of cold water is the way in which the domestic hot water system works. The next diagram shows in simple form such a system. You will see that there are numbered arrows by certain pipes. When you look at the diagram pay particular attention to these.

Now try to answer these questions.

1. In which number pipes will you find cold water?
2. In which number pipes is the water hot?
3. What is the purpose of pipe 2?
4. In the hot water storage tank, will water at "A" be warmer or cooler than that at "B"?
5. Why does the water in the cold water tank remain cold and not warm up?
6. When water is drawn off from one of the taps, this is replaced by water flowing along pipes —— and ——
7. What is the danger if there is a block in the main supply to the cold water storage tank?
8. If this does happen, and the boiler is alight, what should you do?
9. When the tank is full of hot water, why does the water not rise up pipe 3?
10. What prevents flooding should the ball valve in the storage tank become jammed open?
11. Is there any advantage in having the storage tank larger than the hot water tank?
12. How is a tap re-washered?

Copy this diagram in your record books, and colour the pipes red where the water is hot, and blue where the water is cold.

—WATER SYSTEM WORKS



REFRIGERATORS TAKE HEAT OUT

WE have seen that cooling occurs when evaporation takes place. There is another way, however, of cooling a gas. When gases are compressed, as the air is in a bicycle pump, they warm up. On the other hand, when gases are allowed to expand they cool down. Have you ever noticed this effect? Some types of refrigerators work on this principle. Here is a diagram of a simple form of refrigerator that works in this way.

The gas used for this type of refrigerator is ammonia, but this is not the same as the "household ammonia" you may find in the kitchen at home. "Household ammonia" is really ammonia gas dissolved in water.

In the refrigerator when the piston in the pump is on the up-stroke the ammonia is compressed and turned into a liquid. This warms it up, but the liquid ammonia is cooled down as it goes through the pipes in the water jacket. It cannot pass through the valve at 'A' until it becomes a liquid. On the downstroke of the piston, the liquid ammonia evaporates very quickly as the pressure is lowered. Heat is taken from the surrounding brine solution, and intense cold is produced. The brine solution freezes at a much lower temperature than water and it is this cold solution that is sent through pipes in the cold storage chambers.

When scientists were experimenting with liquid gases, they found great difficulty in keeping them cold, for as soon as they began to warm up the liquids evaporated and turned back into their gas form. Sir James Dewar invented the vacuum flask for the purpose of keeping these liquid gases cold. But today we more often use vacuum flasks for keeping liquids hot.

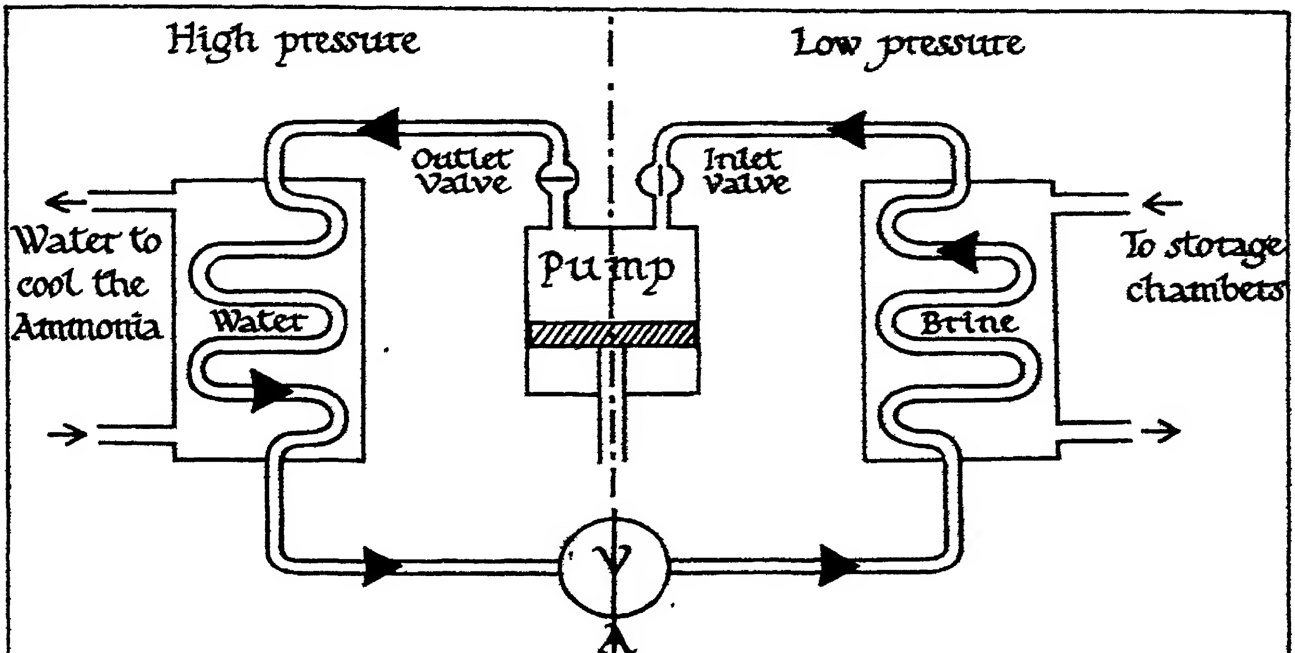
The vacuum flask is an excellent example of preventing heat being lost by all three ways; conduction, convection and by radiation. The double-walled vessel is made of thin glass which is a bad conductor. The space between the two walls is emptied of air so there is no convection. The glass surface is silvered and is very shiny so there is no radiation. The glass seal where the vessel has been evacuated of air stands on a cork and this is a bad conductor and the vessel itself has a bad conductor for a stopper. The whole is protected by a metal casing in which the glass container is fixed by a rubber collar.

Find out what you can about different types of food which are

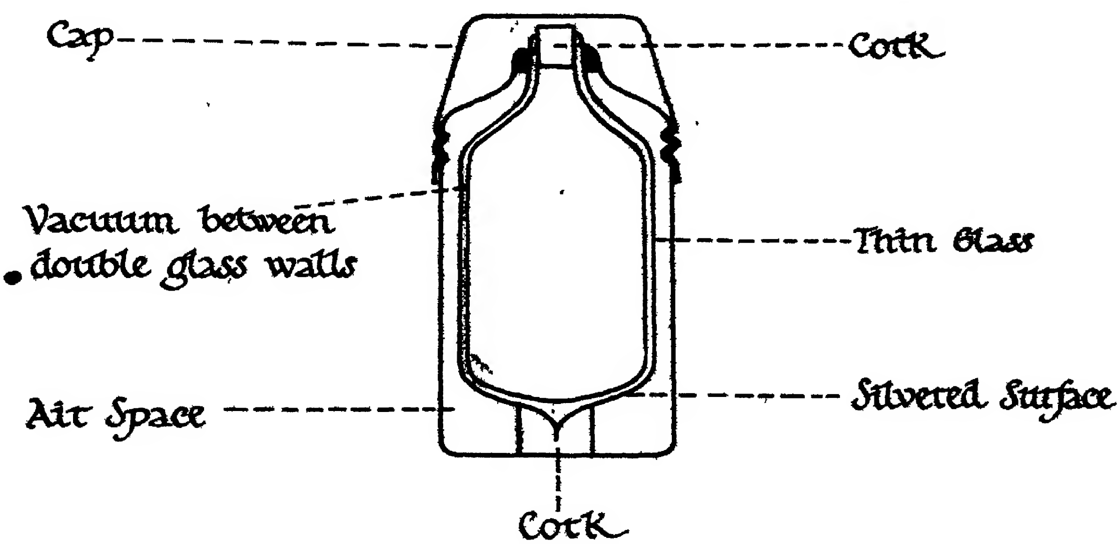
VACUUM FLASKS KEEP HEAT IN

imported today and which were not available in Britain before the invention of ships' refrigerators.

What other types of refrigerators are there? Do any of them use air? What other gases are used?



Valve 'A' does not open until the pressure is high enough to change ammonia gas into liquid ammonia



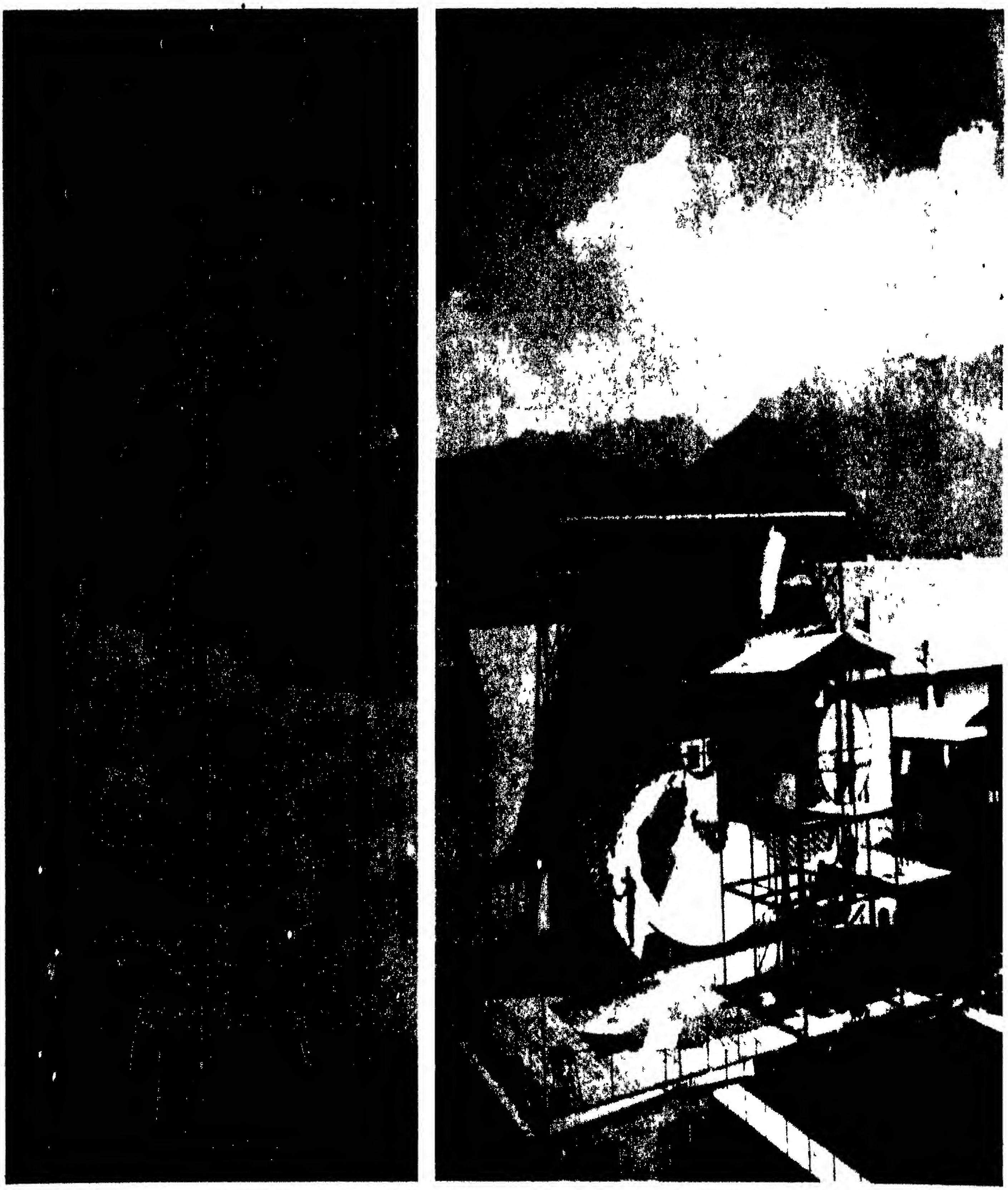
POWER FROM THE WIND AND THE SUN

WE have talked about irrigating the land, and also noticed that there are many parts of the world which could be used to raise food or to provide valuable materials, if only some way could be found to develop the land. Apart from the Arctic and the Antarctic regions, which are very cold areas, there are also certain parts, which total nearly one third of the land area of the world and are useless mainly because they are too dry. These regions are called arid zones. To develop these arid zones, water must be carried to them. To prevent erosion of the soil there must be vegetation. In addition there must be some kind of power.

In Britain and in some other countries most areas are supplied with electricity, and though there are a few remote and thinly populated areas that are without it, the Grid System could supply them. Electricity in Britain is generated mainly by coal or oil. But it would be far too expensive to transport these fuels to the arid zones so as to generate the electricity on the spot. There is, however, an obvious alternative; it is to use the energy already there. Most of these arid zones have natural sources of energy; the sun and the wind. But until quite recently these have not been made use of. Now many governments of these dry areas are beginning to realise how much energy has been wasted in the past, and are trying to find ways of using it. There are many difficulties to overcome. The wind can be used to pump water for irrigation, but will it be blowing at the time when irrigation is most needed? If it is not, then the energy must be stored against the time when water is most needed. Therefore, the climatic conditions of the country must be carefully studied before erecting any pumps. However, some have been put up and you can see a wind-driven electricity generator in the picture here.

On a small scale there are water heaters which make use of the heat energy from the sun, and there are one or two cases of this energy being used to run small water pumping engines. In the other photograph you can see how energy from the sun is used to give a high enough temperature to melt metals. This plant is in the Pyrenees, and the mirror is 36 feet in diameter, and is focused so that the energy from the sun's rays can be used by the "furnace" in front of the mirror.

What are solar cookers, and where are they used?



On the left a wind-driven generator in Germany; on the right a sun furnace in the Pyrenees in France.

WEIGHT MULTIPLIED BY DISTANCE—

LOOK at the children on the seesaw. Why are they at different distances from the pivot? Can the thin child balance the fat one when the latter sits at the end?

From experience we find that, in order to balance, the heavier child must sit nearer the centre of the seesaw. So there must be some relation between their weights and the distance they sit from the centre of the seesaw. Let us try experimenting with a rule, or a thin strip of wood with a hole drilled in the centre. We can use weights of one, two and four ounces, and use loops of cotton to hang them on to the wood or rule. Keep a record of your experiment in your books in the form of a table like the one shown here.

Wt. on left-hand side	*Distance from pivot*	*Wt. × distance*	*Wt. on right-hand side*	*Distance from pivot*	*Wt. × distance*

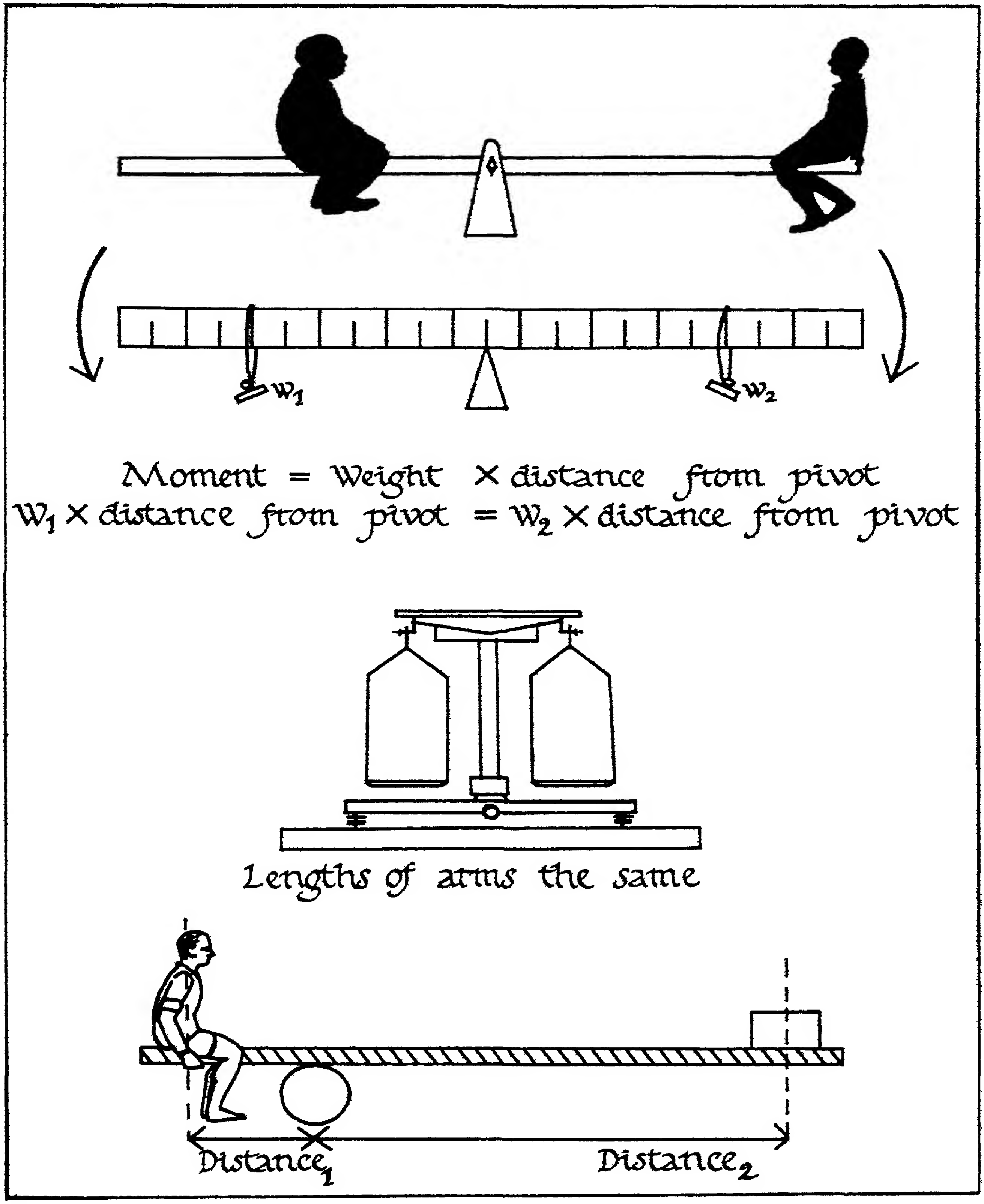
Pivot the rule, and using only one weight on each arm read the distances of each from the centre when the rule will balance. Enter the readings in your table and work out the value of 'weight times distance' in the third and sixth columns. Can you see the connections between these values?

The value given by multiplying the weight by the distance from the pivot is called the "moment" of the force or weight.

The common balance, or scales, is a particular example of this in that it is built so that the lengths of the arms, that is, the distance from the pivot to the point where the pans hang, are the same. In this way the weight of the article that is being weighed will be the same as the weights that are used in the pan.

If you can get some weights large enough, try weighing yourselves in the same way as in your first experiment. In place of the rule use a large plank of wood and pivot it on a log of wood or something similar. You can now balance one of yourselves against your known weight and work out as you did earlier the weight of your classmate. Check this with medical scales if you can. Can you account for any disagreement?

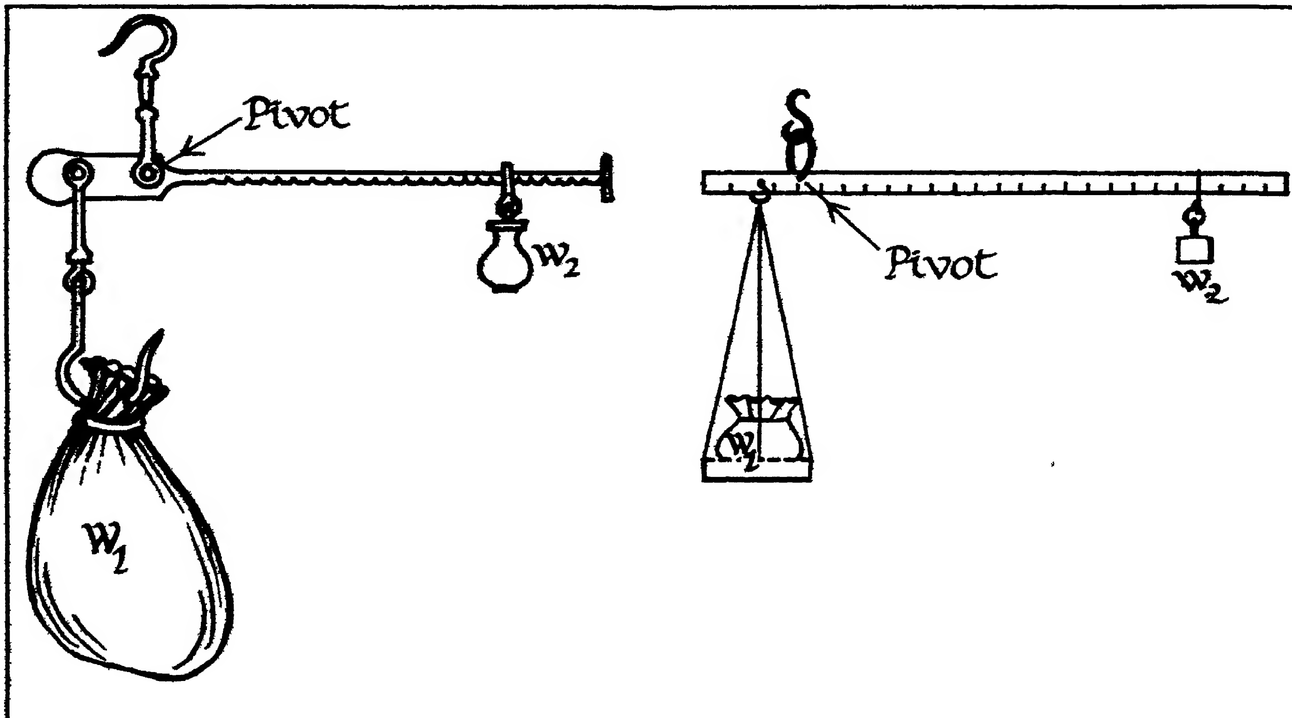
—EQUALS WEIGHT MULTIPLIED BY DISTANCE



THE STEELYARD HAS NOT CHANGED—

A BALANCE or scales with two arms of the same length is not always used. Sometimes very heavy articles have to be weighed. Have you ever seen a butcher using a "steelyard"? This makes use of the principle you saw when you experimented with the weights and the rule. The heavier weight is always nearer the pivot than the smaller. Because of this, we can always "balance" heavy weights on the short arm by a few small weights on the long arm. What is the advantage of this method which was known to the Romans centuries ago?

You can make a steelyard very easily with either a wooden lath or a strip of metal such as brass. Use a strip of wood a yard long and drill a hole 4 inches from one end and a little towards one edge. Using a tin lid for a pan, suspend it from the strip of wood by means of a wire stirrup as shown. The stirrup is fixed in a hole drilled 2 inches from the pivot. A piece of lead is attached to the shorter arm to act as a counterpoise. Why is this necessary? Now mark off the longer arm in 2 inches and then sub-divide these divisions into inches. In the pan



$W_1 \times$ distance from pivot $= W_2 \times$ distance from pivot

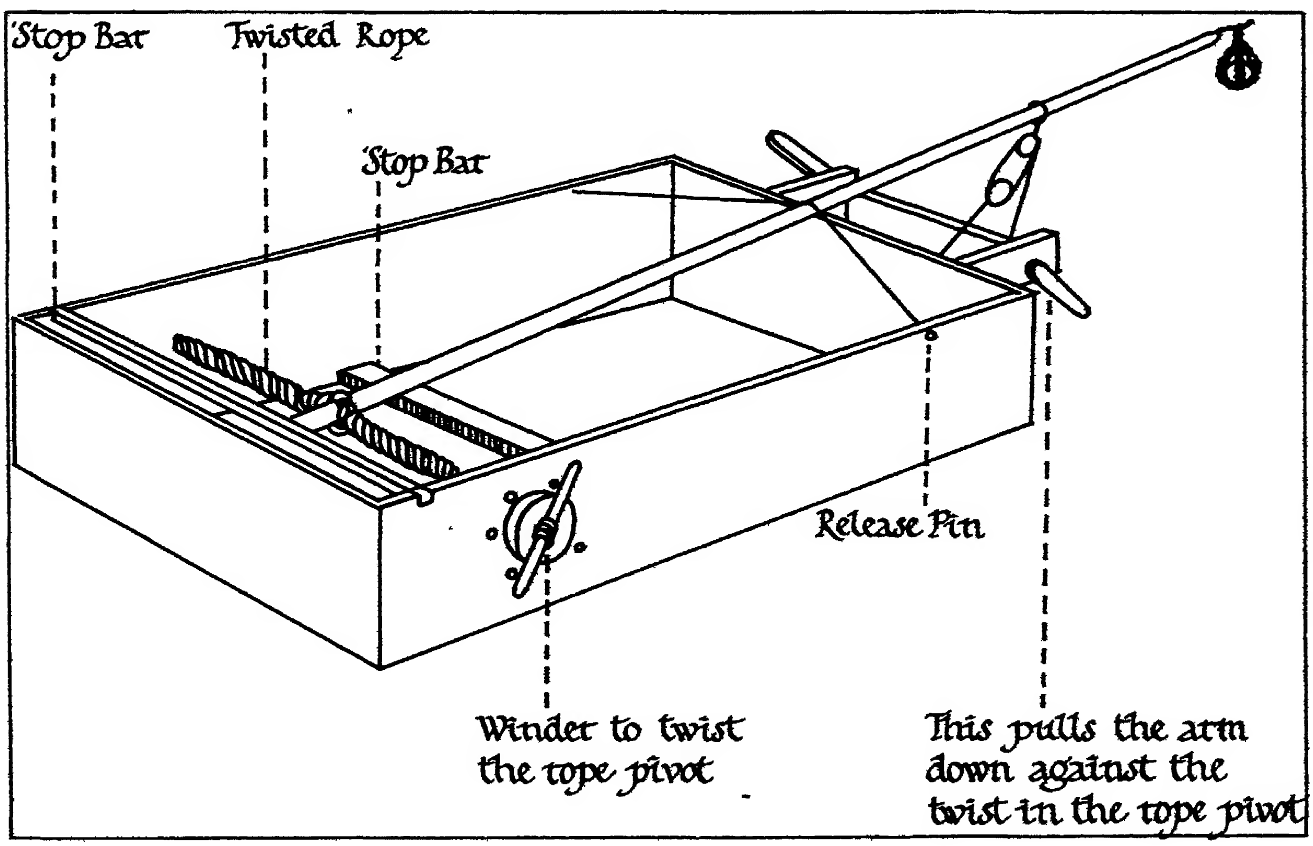
—THROUGH THE CENTURIES

is put the unknown weight which will always be at a fixed distance from the pivot. This is balanced by a much smaller known weight on the longer arm at a bigger distance from the pivot. Suppose that the smaller weight is 1 ounce and is 28 inches from the pivot. Then using our discovery about weights and distances that we made last time,

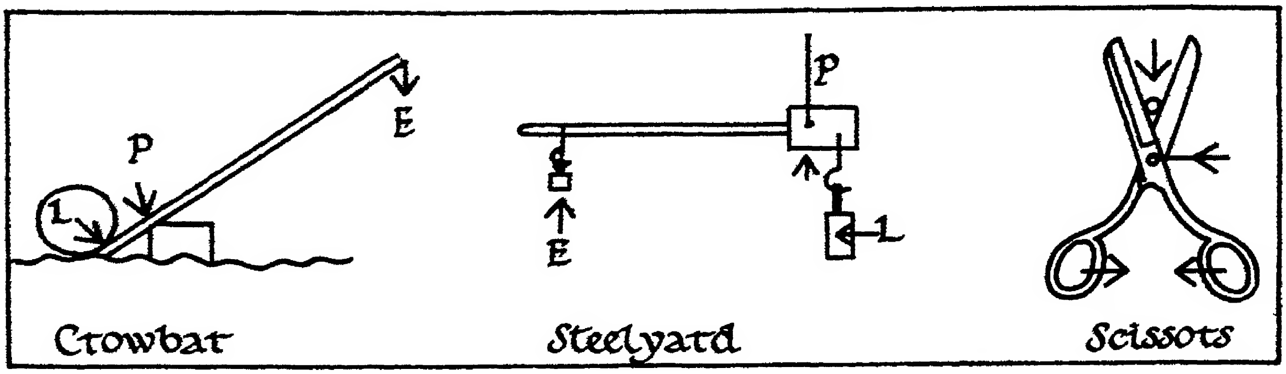
$$\text{Weight in pan} \times 2 \text{ inches} = 1 \text{ ounce} \times 28 \text{ inches.}$$

From this we can see that the weight of the article in the pan is 14 ounces. By this means we can weigh articles using weights much smaller than the weight of the article to be weighed, and only a few weights will be needed. If the balance point is between two divisions, what do you do?

One of the ancient weapons of war was the catapult. If you look at the drawing you will see how it worked. Can you see any connection between the steelyard and the catapult?

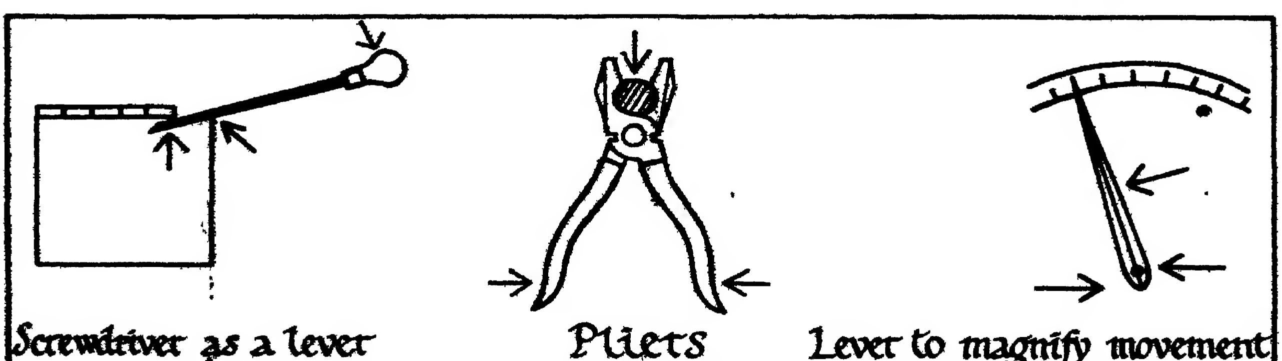


USING A LEVER MAKES—

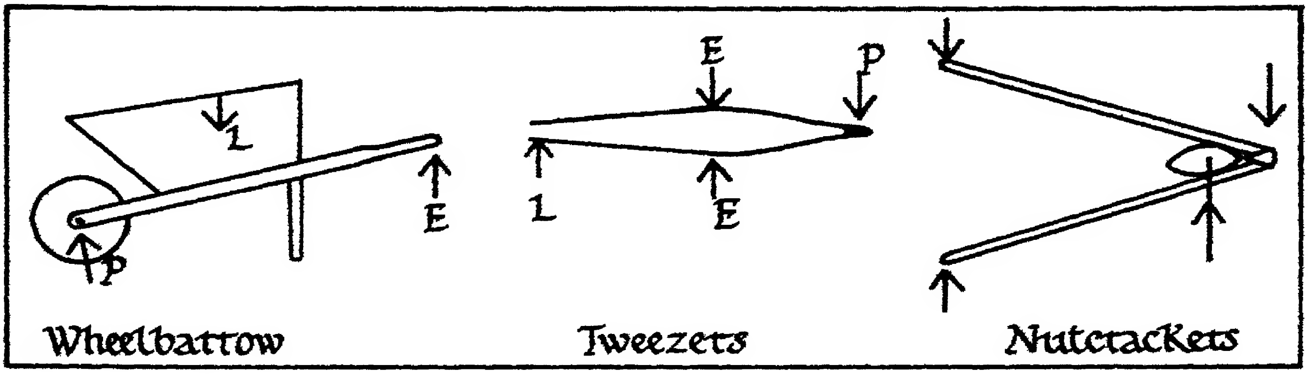


ABOVE are several drawings and you will see that there is something common to them all. What is it? Each drawing shows an invention to make easier the carrying out of a job. Each can be likened to a balance arm, some having arms of equal length and some having arms of unequal length like the steelyard. Each has a pivot or point (P) about which the arm turns, while at one end there is something that is being "lifted" or moved like the unknown weight on the balance. This can be called the load (L), and at the other end there is the effort (E). The effort has to be made to move the load; the weights provide it on a balance. Copy these drawings into your record books, completing the pictures by labelling the arrows in the same way as the first drawings here have been labelled.

With most of these levers, the pivot is much nearer the load, as in the case of the crowbar. Why is this? When is it easier to lift the log, when the pivot is near the log or when it is near the man using the crowbar? Think of the steelyard. In the same way we have a large weight or load moving a short distance being balanced by a small weight or effort moving a bigger distance. When we wish to magnify movement, we use a lever, and then the point that registers the



—MANY TASKS EASIER

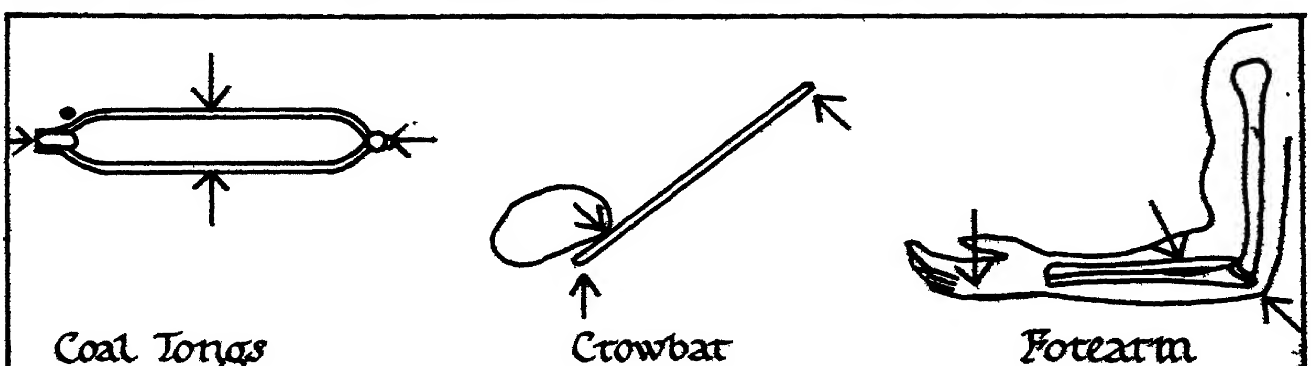


movement is farther from the pivot than the effort. Consequently only a very small load is needed to stop the movement of the lever.

Now study the second set of drawings. Again we have ways of doing a certain amount of work in a convenient manner. How do these machines differ from those in the first set of drawings? Here you will see that the pivot is at the end of the lever, whilst either the load or the effort is nearer the pivot. Some of the drawings have arrows labelled, and others have arrows that are unlabelled. Copy these into your record books, as you did the first set of drawings, and complete the labelling of the arrows in the same way. As with the first set of levers, the same relationship between effort and load and distance applies. In which of these is the effort greater than the load?

There are many more examples of levers than the few shown here. Make drawings of others that you can think of and label arrows as you have done with the others.

What do you mean by the word "machine"? We shall see how simple machines were used to lift a heavy column of stone.



LIFTING A STONE COLUMN—

IT may seem that you are getting something for nothing when you use a lever, such as a crowbar, to lift a heavy weight. When the pivot, or "fulcrum" is near the heavy load, it does not need a great effort on our part to move the longer arm, and so to lift the weight. But we must remember that, in order to lift the weight a short distance, the end of the arm to which we apply the effort has to move much farther.

In front of St. Peter's Church in Rome there is a tall stone column which weighs hundreds of tons. This was erected nearly 400 years ago, before the crane and the elaborate hoisting gear we are so familiar

The erection of the column in St. Peter's Square, Rome, in 1586, using pulleys and capstans.

—WITH THE SIMPLEST MACHINES

with today were available. There was no steam or electricity to supply power; it had to come from the muscles of men and horses. Simple machines were used. In order to lift the column vertically, wooden towers were built on either side of the base. From these erections were suspended pulley blocks with other pulley blocks fixed to the column itself. One end of each rope was attached to one of the pulley blocks while the other was fastened to a capstan. The capstans were turned by long bars, and very slowly the column was raised into position.

The power that was used moved a great distance, while the load that was lifted moved only a short distance.

A capstan and pulleys in use on board a modern racing yacht.

CAPSTANS AND PULLEYS—

PERHAPS at first sight the capstan may not look very much like a lever, but remember that it has a pivot, an arm (X) which can be pushed, and an arm (Y), that will move a load. The diagram makes this clear. The pivot (P), or fulcrum is the centre of the circle and the short arm of the lever will be the length of the radius of the capstan. From the drawing you can see that if one arm (X) is six times as long as the short one (Y), the effort needed to turn the capstan need only be equivalent to one-sixth of the load. How do the distances that the ends of each arm travels compare?

As well as the capstans and the pulley blocks in the picture showing the hoisting of the big column, there are also some single pulleys. What are they for? Do they give any advantage in the way that a lever can help us?

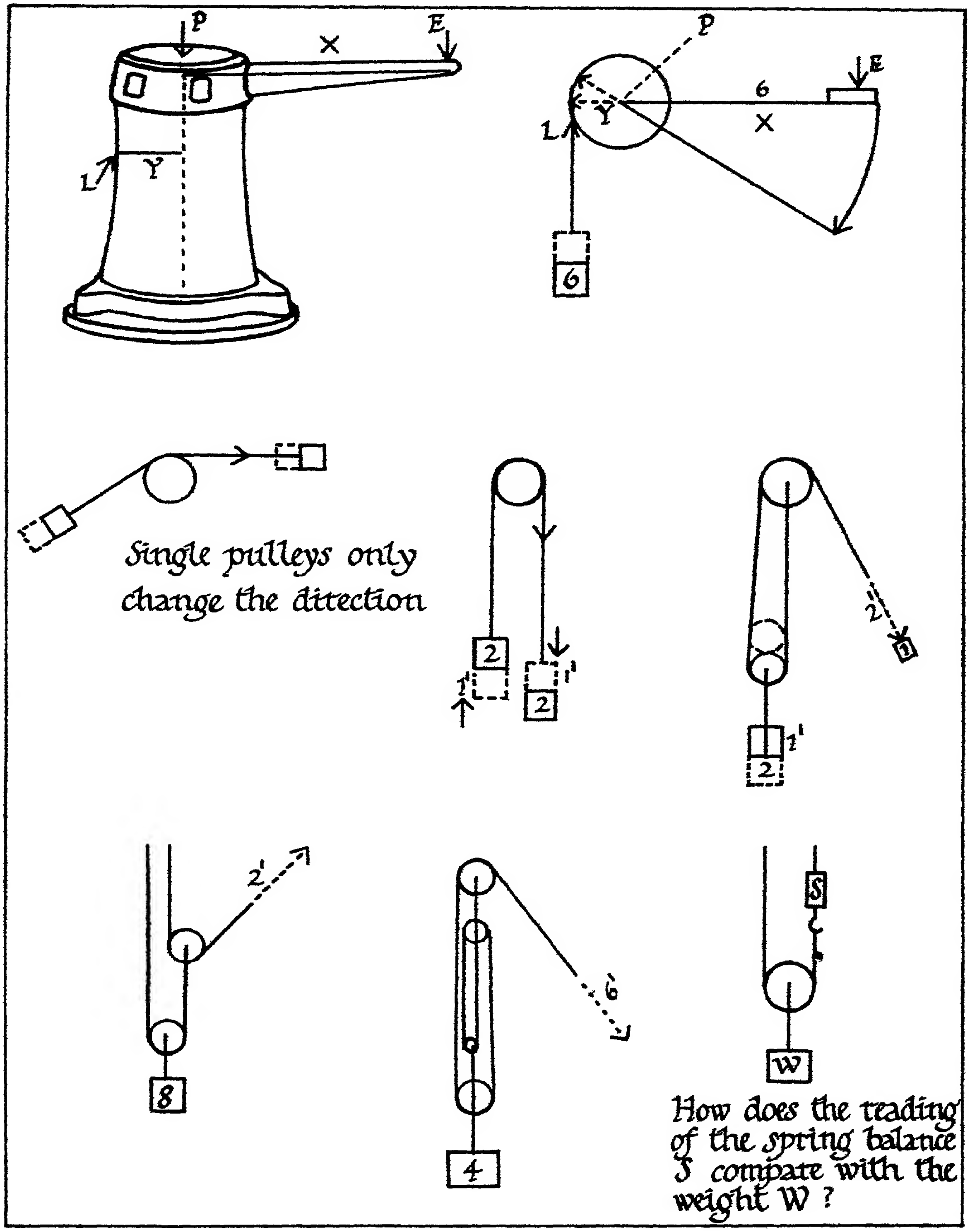
Now look at the diagrams here of the pulley systems. In the case of the single pulley you will see that the only effect is to change the direction, for the load and effort have to move the same distance. In the third diagram there are two pulleys and in this case a pull of one pound will raise a load of two pounds. Again however, it is not a case of something for nothing, because as you can see, the free end of the rope has to be pulled two feet to raise the load one foot.

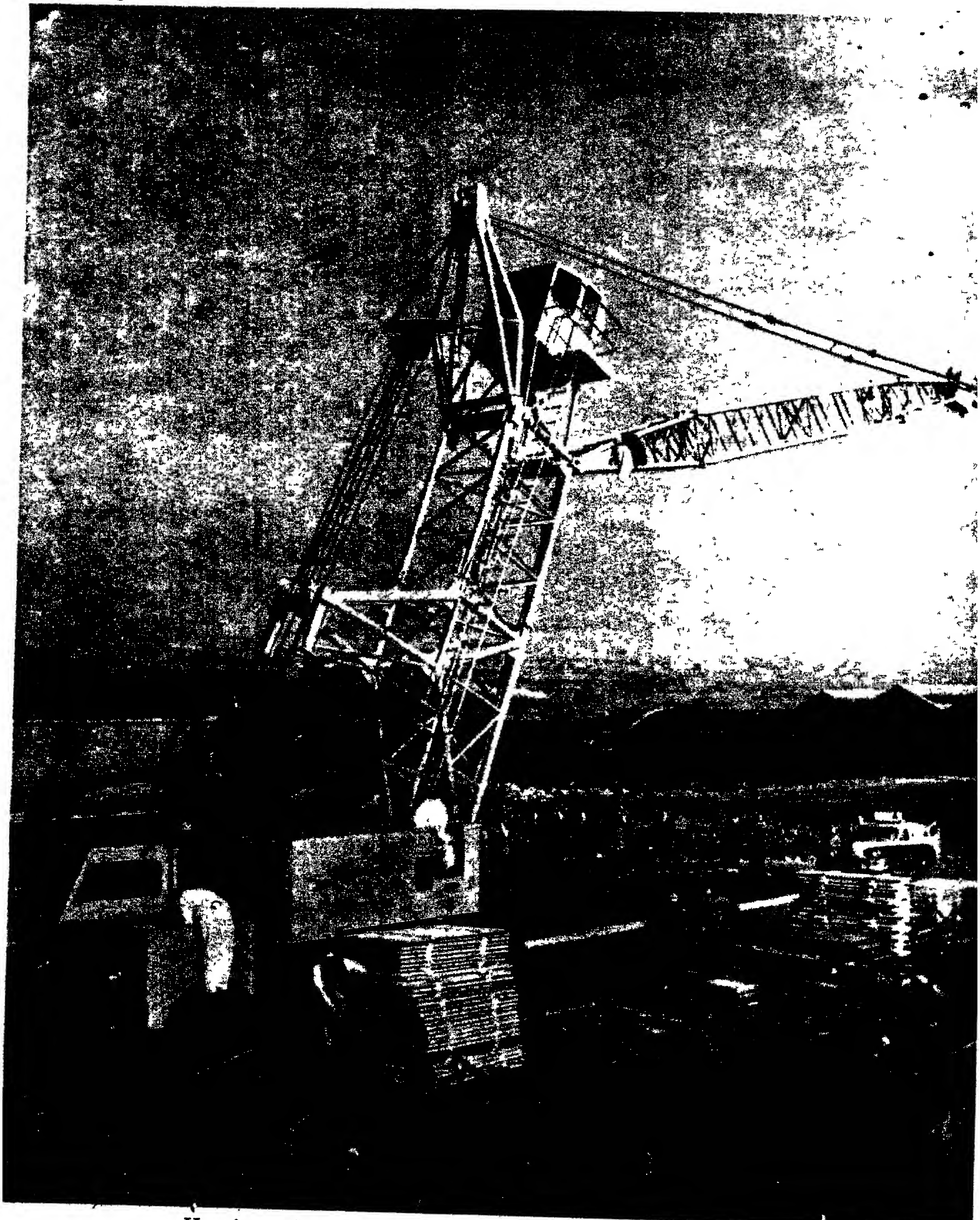
Either using pulley blocks, or by making them up for yourselves, from separate pulleys, axles and metal or wood strips, set up the systems shown in the rest of the diagrams. Often in these pulley blocks, the pulleys are side by side on a common axle instead of being arranged as shown here. You will see that the first two diagrams give you the values of the pull and the load as well as the distances that they move, the rest do not. If you can, set these up for yourselves and then find the missing figures. If you cannot do this try to work them out for yourselves, but do not mark the diagrams in this book; copy them into your record books and try them there. Does the diameter of the pulleys matter?

On the next two pages you will see pictures showing the use of levers and pulleys in everyday life. Can you say what advantages they give us? Try to collect some pictures for your record books from newspapers or magazines.

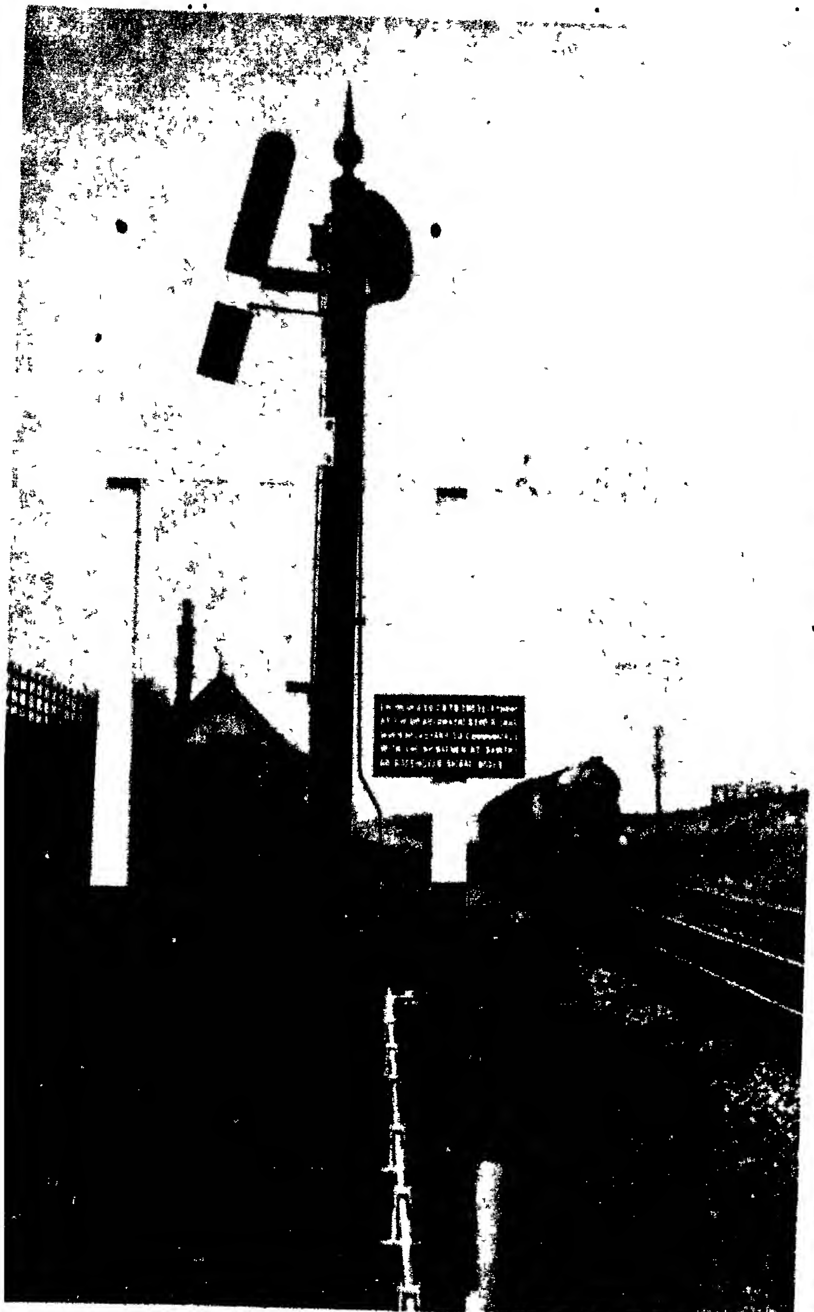
Make a drawing of a bicycle and label the simple machines such as levers that are used in its construction.

—ARE SIMPLE MACHINES





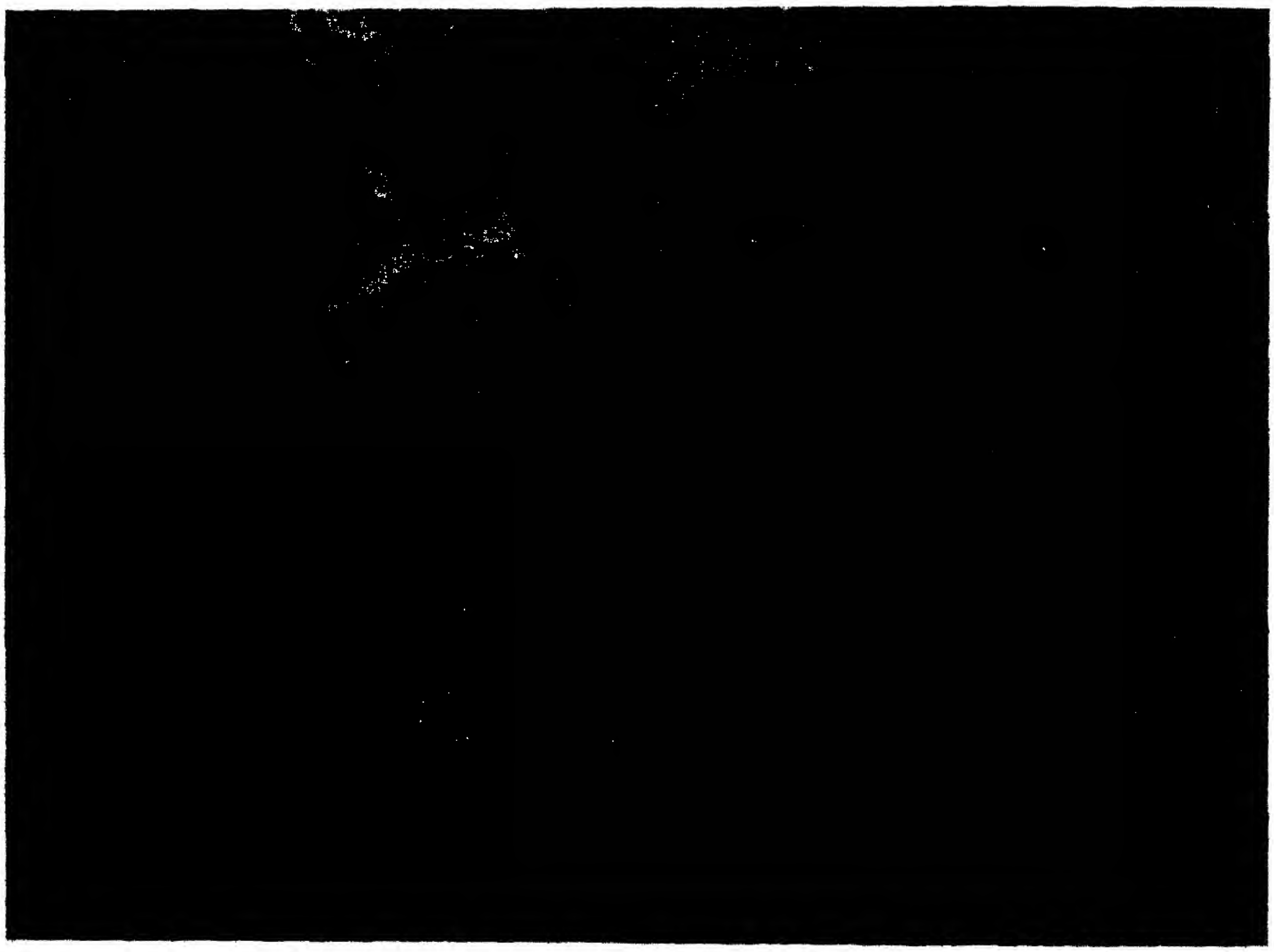
Here is a mobile crane which makes use of many levers and pulleys. How many can you see?



A system of levers is used in semaphore as opposed to electric signalling so that movement of a signal at a distance can be controlled easily from a signal box. Can you trace the sequence of movements and suggest the types of levers that might be used?

ROADS AND RAILWAY LINES—

WE have seen how difficult it must have been to move the huge stones that were used to build the Pyramids. It is generally thought that, when these large stones were moved, they were run on some rather crude form of roller. Although this would simplify the task of getting the stones to the site of building, it would not help in the erection of them. How then were the stones put one on top of the other? To ride up a steep slope a cyclist has to work harder than when he rides up a gentle slope. In using a ladder when do you find you need most effort to go from one rung to another, when the ladder is at a steep angle or when it is at a gentle one? Do the distances between the rungs matter? When the ladder is at a steep angle you need a greater effort to go from one rung to the next, but, on the other hand, you do not need so many rungs to get to the top, as you do when



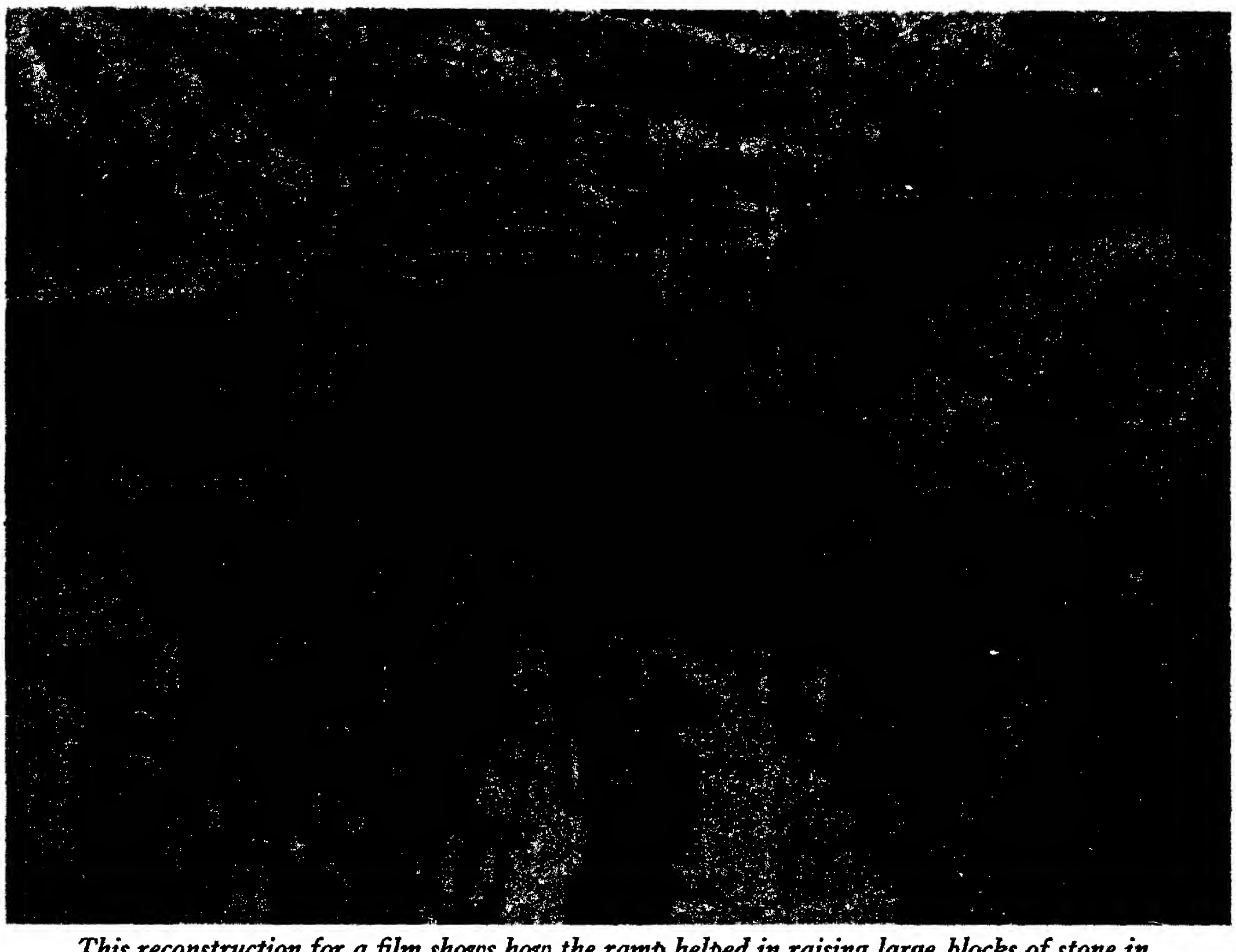
A zigzag railway in Peru.

—ARE SOMETIMES "ZIGZAGGED"

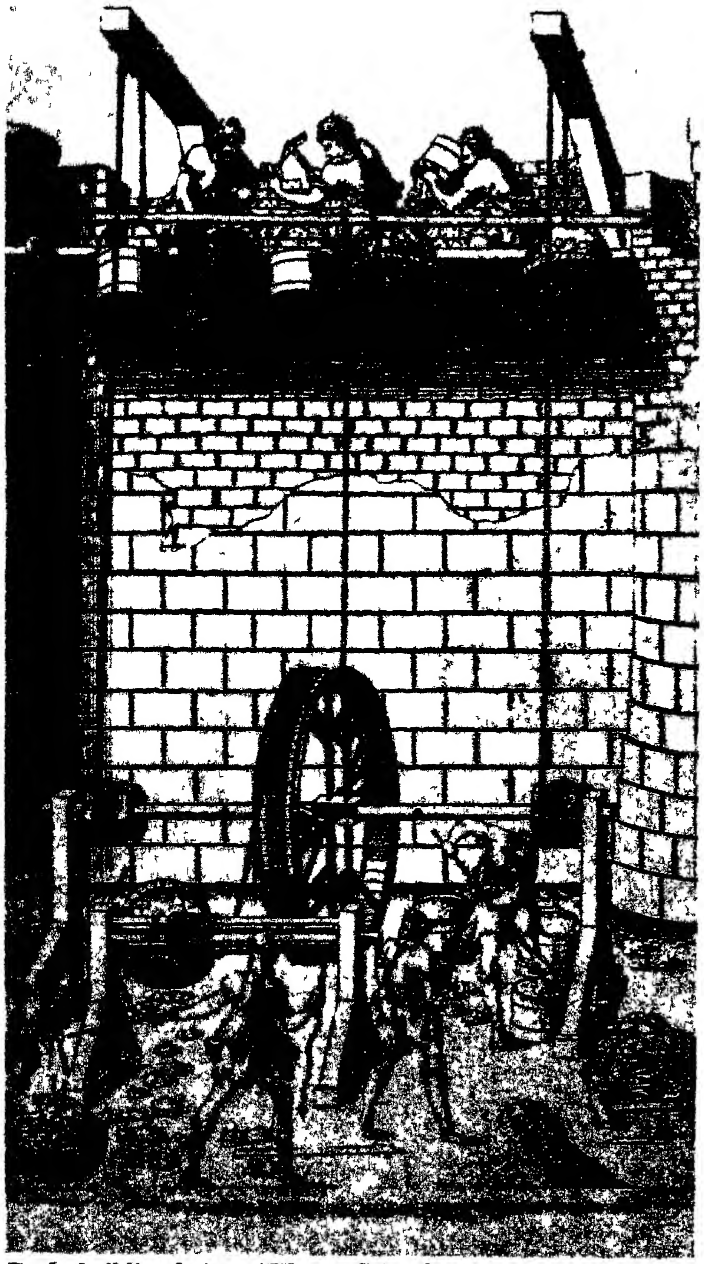
you have the ladder at a gentler angle. So when we consider slopes, we must also consider distances.

When the pyramids were being built it is probable that these huge stones were dragged up a ramp which had to be built specially for the purpose. As in climbing the ladder, the longer the slope the easier the task became, although a very much longer pull was required.

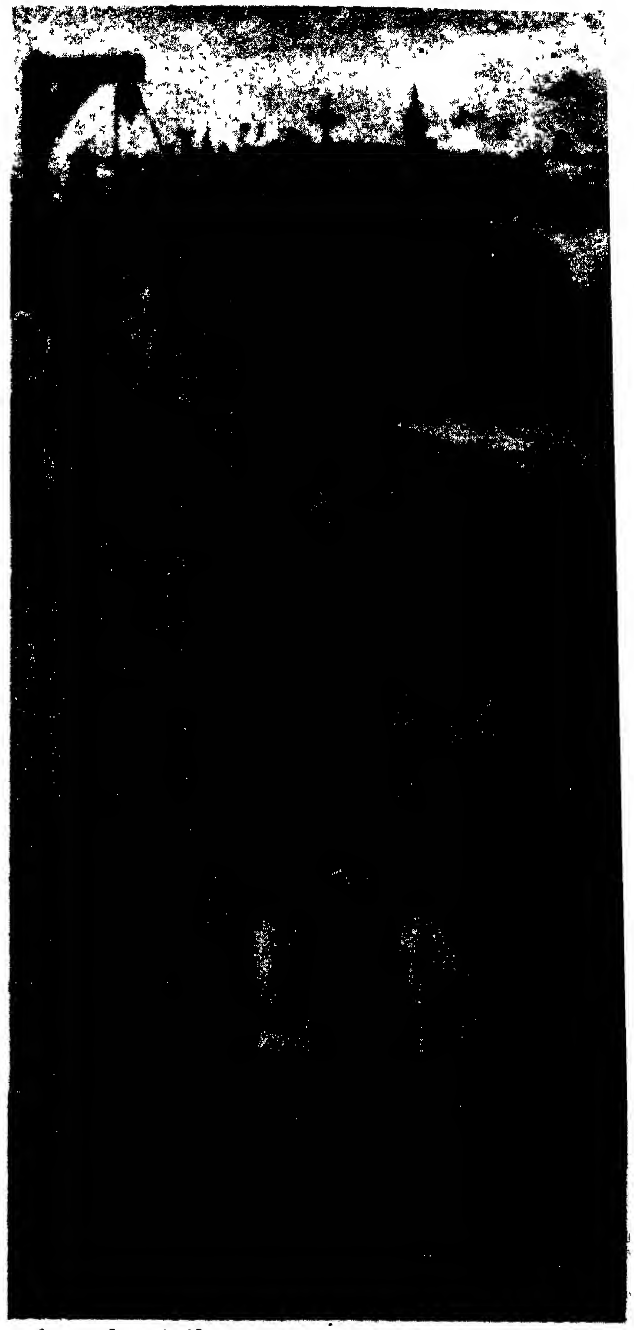
This fact was used sometimes when railway lines and roads were built. If the slope of the ground is too steep for the lines and the roads to follow, they are built in such a way that they wind, and, although this makes the distance to the top very much longer, it means that the transport needs less energy every yard that it has to travel. Of course, the total energy required to get to the top is the same in both cases.



This reconstruction for a film shows how the ramp helped in raising large blocks of stone in ancient Egypt.



Early building hoists. What will be the advantage in altering the diameters of the drums and pulleys?



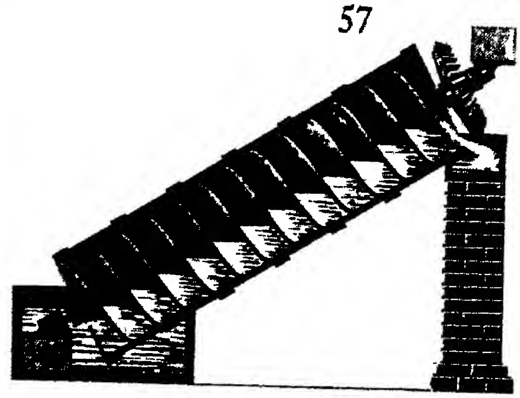
An early windlass. Is it being used as efficiently as possible?

MACHINES REDIRECT EFFORT—

THE lever, the "inclined plane" or slope and the pulley are simple machines. Have you decided what we mean by a machine?

A machine allows us to use a force in one place and to get the effects of it elsewhere. It helps us to do something that otherwise would have

An early French printing press. Is there any advantage to be gained by increasing the leverage and altering the pitch of the screw?



The Archimedean Screw. The operator is turning the handle which makes the screws revolve (see diagram) and thus raises the water to the new level.

—TO BETTER ADVANTAGE

been more difficult or inconvenient, it redirects effort to better advantage.

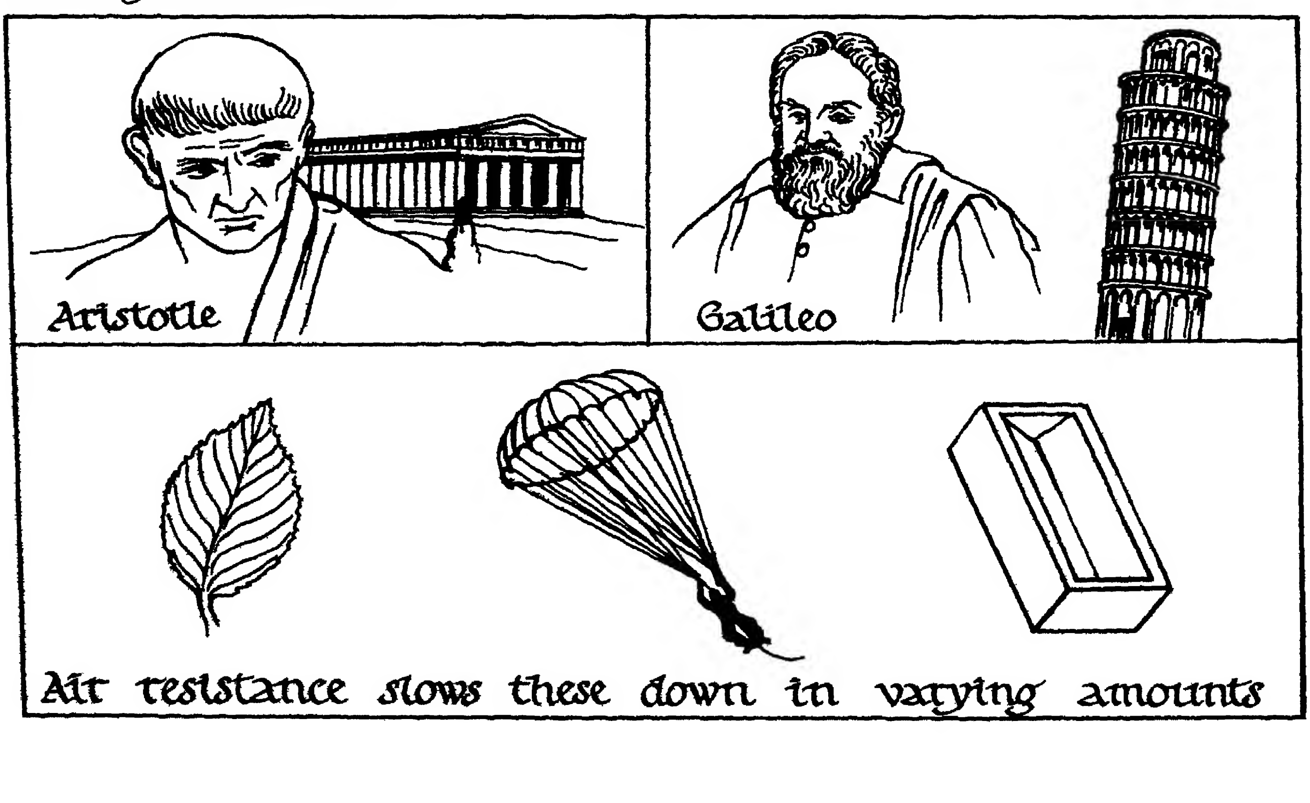
Here we have some pictures of some early machines and the way they were used. Can you see what the advantage of each machine is? Could another simple machine do the task as well or better?

HOW GALILEO'S STONES DESTROYED—

MANY years ago there lived a very famous man, named Aristotle. He spent much of his time thinking about scientific problems. One of the problems that he and other men living at that time discussed was that of "falling bodies". As a result of these discussions it was said that the denser the body the faster it falls. Some of our everyday observations confirm this. Leaves fall down to the ground far more slowly than tiles from a roof.

Unfortunately these early philosophers spent all their time talking about these problems and making certain theories about them, without ever testing them out. For nearly two thousand years Aristotle's theory about the way in which things fall was accepted by everyone without question; no one bothered to test it. Can you tell from the drawing where Aristotle lived?

Between the years 1589 and 1591 in a series of startling deductions the idea believed for so long was disproved. Instead of arguing about the way things fall, an Italian named Galileo dropped stones to the ground. He used a variety of sizes, large, small, round and flat stones. If they were all released together they all reached the ground at the same time. Galileo repeated this experiment dropping stones from the famous leaning tower of Pisa.

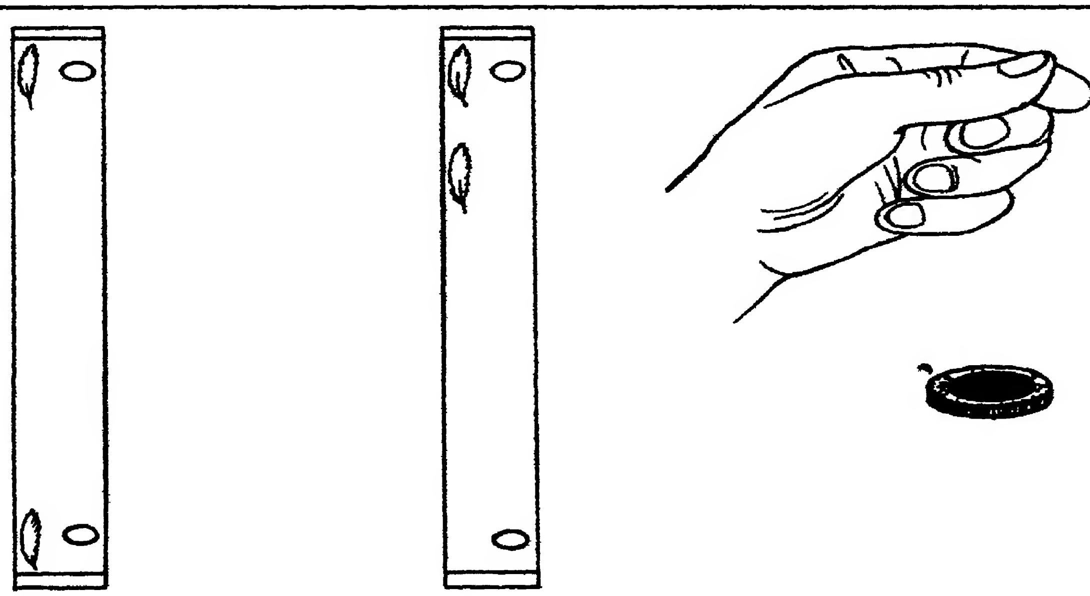


—ARISTOTLE'S THEORY

You know already that falling tiles reach the ground more quickly than falling leaves. Why is this? Think about wind resistance as we did in considering the parachute. If the falling object is fairly light, then the wind resistance will play a very important part in regulating the fall. A feather and a penny will fall at different speeds if they are released together into a long glass tube. When all the air is removed from the tube they will fall at the same rate.

You can try this in a slightly different way for yourselves. Place a small piece of paper flat on a penny, the paper must not overlap the edge of the coin. Hold them between your finger and thumb and release them very quickly. The coin and paper will reach the ground together. In this way the penny shields the paper from the air underneath it as it falls.

When Galileo was experimenting with the speed at which things fall he had no accurate watch or clock to measure time with. Instead he used water. It was allowed to drip into a basin, and the amount collected was weighed. This gave him a means of comparison. Although it was perhaps rough and ready by modern standards, it did enable him to prove that when bodies fall they accelerate. What does acceleration mean?

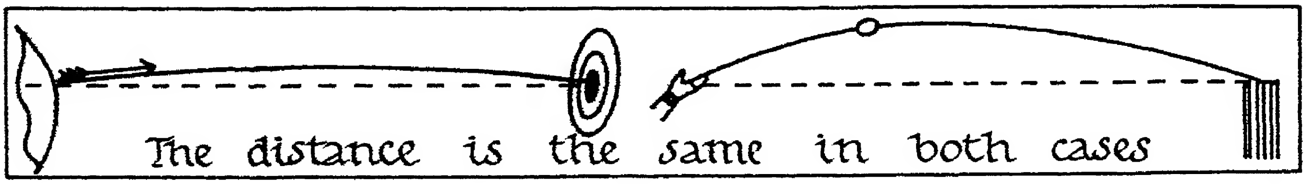


A coin and a feather fall at the same rate in a vacuum

They fall at different rates in air

A coin and a piece of paper fall together in air

FALLING BODIES ARE ACCELERATED—



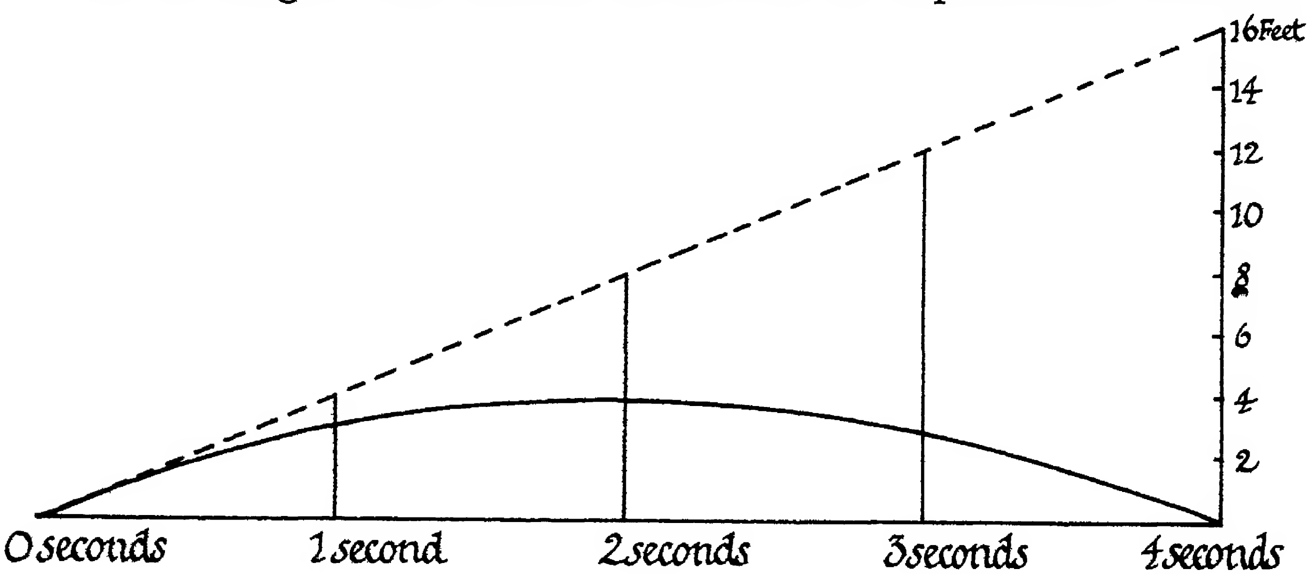
LOOK at the drawings on this page and see if you can answer these questions:

1. What have the drawings in common?
2. What does the dotted line show?
3. Which travels the faster, the arrow or the ball?
4. Why do they travel in a curved line?
5. Which has the flatter curve? Why?

When you aim with a ball at cricket stumps or at a mark on a wall from a distance, you aim above the target, knowing that the ball will fall as it travels. Unless you do this the ball will probably not reach the target, or if it does, will be low.

As soon as the arrow, or ball, leaves the bow or hand, it is pulled towards the earth, so that if it is to reach the target, it must be aimed high. The next diagram shows how big the pull is. Although the scale is exaggerated, you will see that after the arrow or ball has been travelling for one second it has been pulled down one foot, after two seconds four feet, and so on. How far has it been pulled down after three and four seconds?

Let us imagine that Galileo carried out his experiments from the



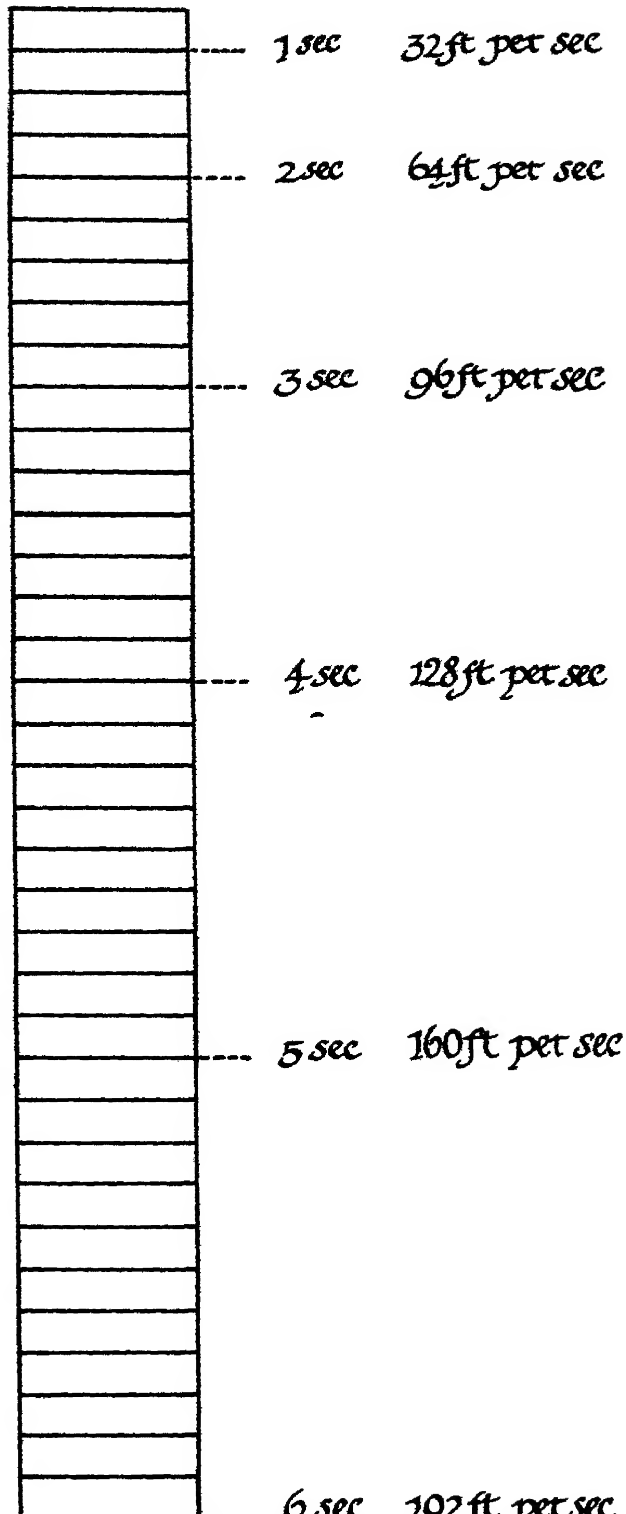
—THE ACCELERATION IS DUE TO GRAVITY

top of a skyscraper instead of from the leaning tower of Pisa. Our skyscraper has thirty-six stories each 16 feet high. After one second the stone released at the top falls one story, after two seconds four stories, and so on. What distance does it fall in six seconds?

What distance does the stone fall in the first second, in the second, in the third, and so on? You will see that the stone travels farther in each successive second. The stone is accelerating. What causes this acceleration? You will see that every second the stone travels 32 feet per second faster. It is accelerating at the rate of 32 feet per second every second. This acceleration is due to gravity.

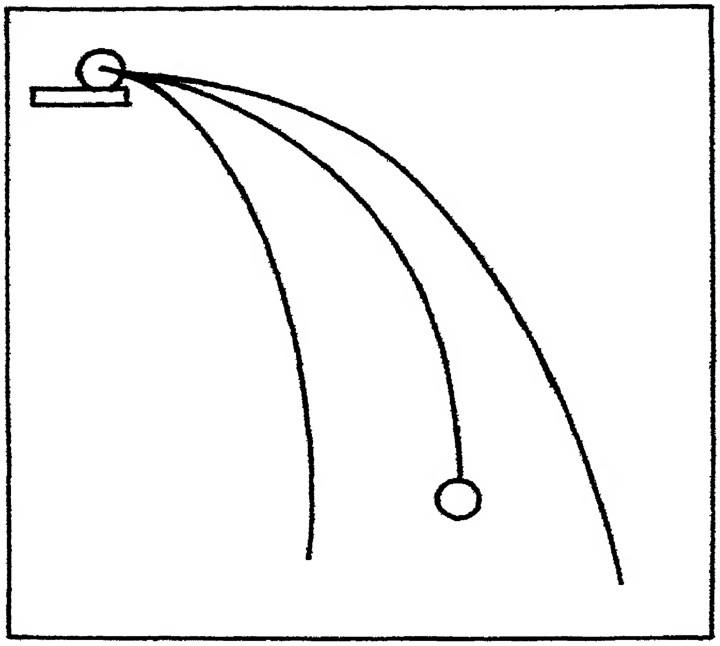
By the time the stone reaches the ground it is travelling at the rate of 192 feet per second, or about 130 miles per hour. Of course the faster the speed the greater would be the effect of resistance of the air, but it is still travelling very fast. No wonder hailstones sometimes do very considerable damage.

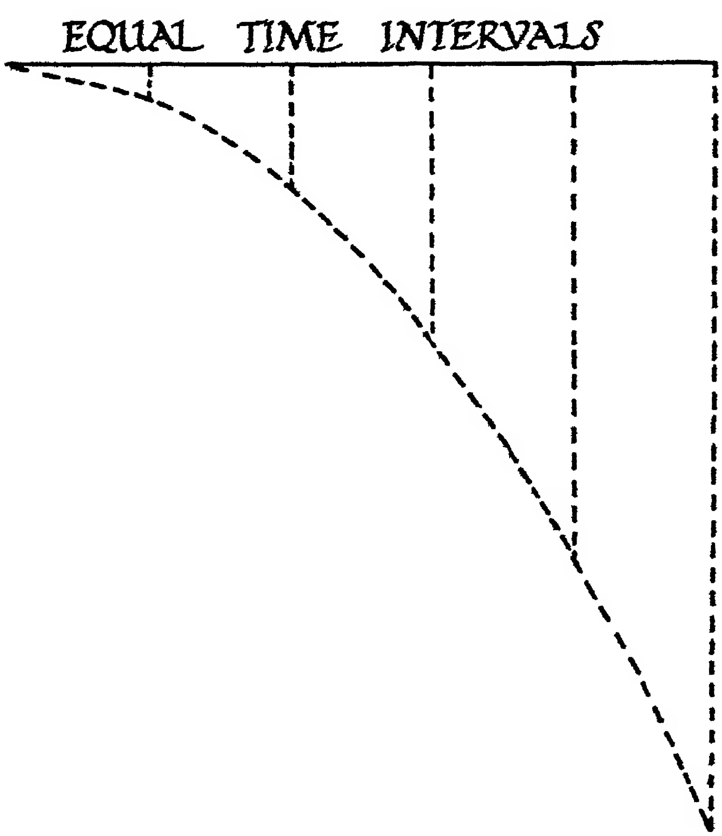
At what speed would a stone have to be shot up into the air to reach the top of the skyscraper? How many stories high must the building be for the stone to take 7 sec. to fall from the top story to the ground?



36 units representing stories of a skyscraper.

CURVES

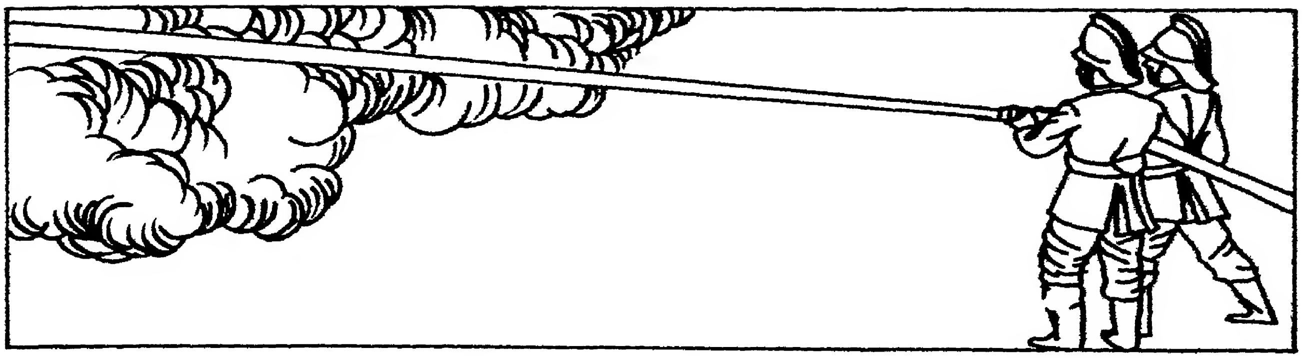




IT is not very easy to trace the path that a ball takes when it falls freely, but it is much easier if we can slow down the fall. Fasten a large piece of paper to a board. You can use the top of a table if you like, but cover it with newspaper. At the top left hand corner of your board or table fix a piece of wood as shown in the diagram. Mix up some red poster paint with water, then thoroughly coat an old tennis ball with it. Use poster paint and then you can wash it off afterwards.

Now tilt your board, or table, so that it slopes gently. Place your reddened ball so that it rests on the piece of wood. Carefully push the ball forward so that it rolls off the wood and down the covered board. The ball traces out a curved path. If there are one or more gaps in the curve complete it with some of the paint.

From the point at which the ball begins to fall draw a horizontal line across the paper. Along this line mark several points at equal distances from each other, beginning at the point from



which the ball began to fall. These marks represent equal times. From them draw lines vertically down to the curve traced out by the ball. Measure these distances giving the distances that the ball has fallen in the time intervals.

As you saw earlier on, the ratio of these distances is 1, 4, 9, 16, 25. How do your measurements compare with these? They may not agree exactly, because of the speed of the fall is slowed by the resistance, but they should not be far out.

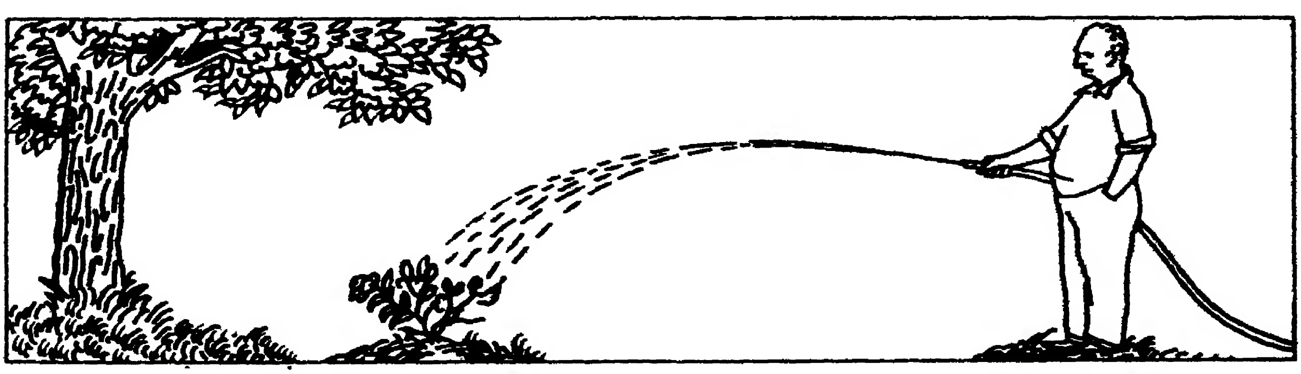
If the ball is merely allowed to fall from the edge of the piece of wood it will fall in a straight line, whereas if it is pushed forward hard the curve will be flatter at the start than the one you have just traced out. The way in which the curve varies with the forward speed is shown very well with the garden hose. The faster the stream of water, the flatter the path that the water takes.

Can you answer these questions?

(*a*) At what angle would you throw a cricket ball in order to send it as far as possible?

(*b*) What do you notice about the numbers 1, 4, 9, 16, 25?

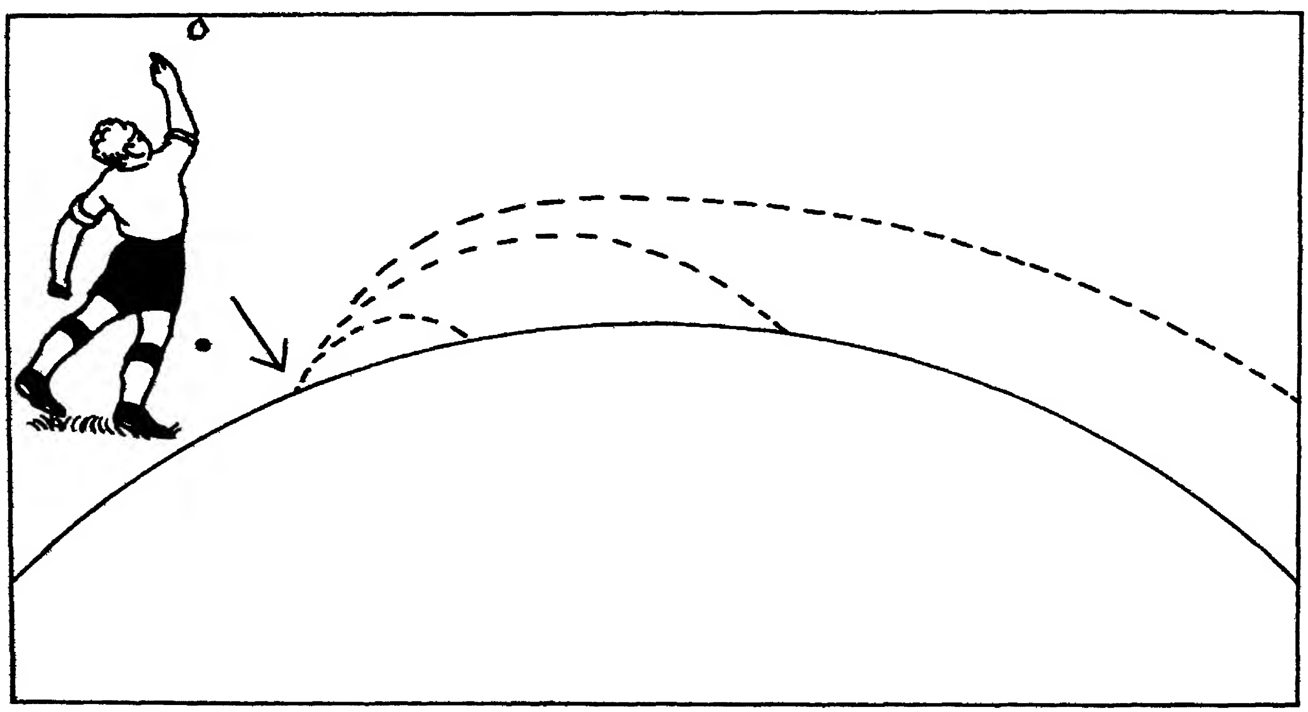
(*c*) Why does the ball in the experiment accelerate?



HOW SIR ISAAC NEWTON DISCOVERED—

WE know that when arrows are shot, cricket balls thrown, and stones dropped from towers they all fall to the earth. If they have any forward movement, they will not fall straight down, but they will come to earth eventually. Another very famous man, Sir Isaac Newton, set himself the task of explaining why the moon keeps a regular path round the earth. There is a story that Newton, sitting in a garden, saw an apple fall to the ground and from this he reasoned that there must be some form of attraction between the earth and the apple. He showed that this is a very real force, this gravitational pull of the earth. It is this force that is responsible for the path not only of the moon, but also for those which the earth and the planets take round the sun. Because of the work done by Newton, and by others too, it is possible to predict the position of the various planets, as well as such things as the eclipses, years in advance.

If the moon is being continually pulled towards the earth why is it that it never gets there? Probably you have swung a stone round on the end of a piece of string. When you do this you are continually pulling it towards your hand at the centre but it never reaches the centre because of its speed. Suppose that, when you had got the stone whirling as fast as possible, you suddenly released it. What would



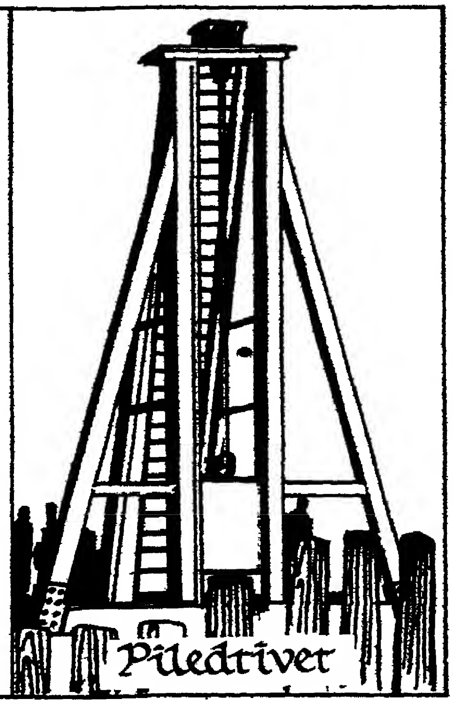
happen? It would still fall to the ground. However, if you could whirl it very fast indeed before releasing it, so that when released it cleared the atmosphere, and therefore met no air resistance, providing its speed was high enough it would go on and on at the same speed, circling the earth. It would tend to fall to the earth because of the gravitational pull; but its own speed would prevent it from ever getting there.

One of the many ways in which the acceleration due to gravity is made to do work for us is shown by the pile-driver. A very heavy weight is raised by an engine and then released. As it falls it accelerates and hits the pile into the ground. Can you think of any other examples like this?

Until the time of Galileo there was no accurate method for measuring short periods of time. Sundials, burning candles, and the dripping of water were some of the means used. All these methods were very inaccurate and the greatest advance in timekeeping was the discovery that a pendulum of a given length always took the same time to make a complete swing. This time is affected by the acceleration due to gravity. Many of our clocks today make use of the pendulum and thus the acceleration due to gravity.

Sir Isaac Newton

Gravity causes apples to fall and eclipses to occur



MEASURING A CURRENT—

WHEN an electric current is flowing in a circuit it can produce three effects as we have already seen, they are:

1. The heating effect as in an electric lamp.
2. The chemical effect used in electroplating.
3. The magnetic effect as in electromagnets.

An electric current can be obtained either from a stored supply such as the accumulator or dry battery, or direct from a dynamo. We will be dealing with these matters later.

The heating effect of a current can be used to measure the size of current that is flowing in a circuit.

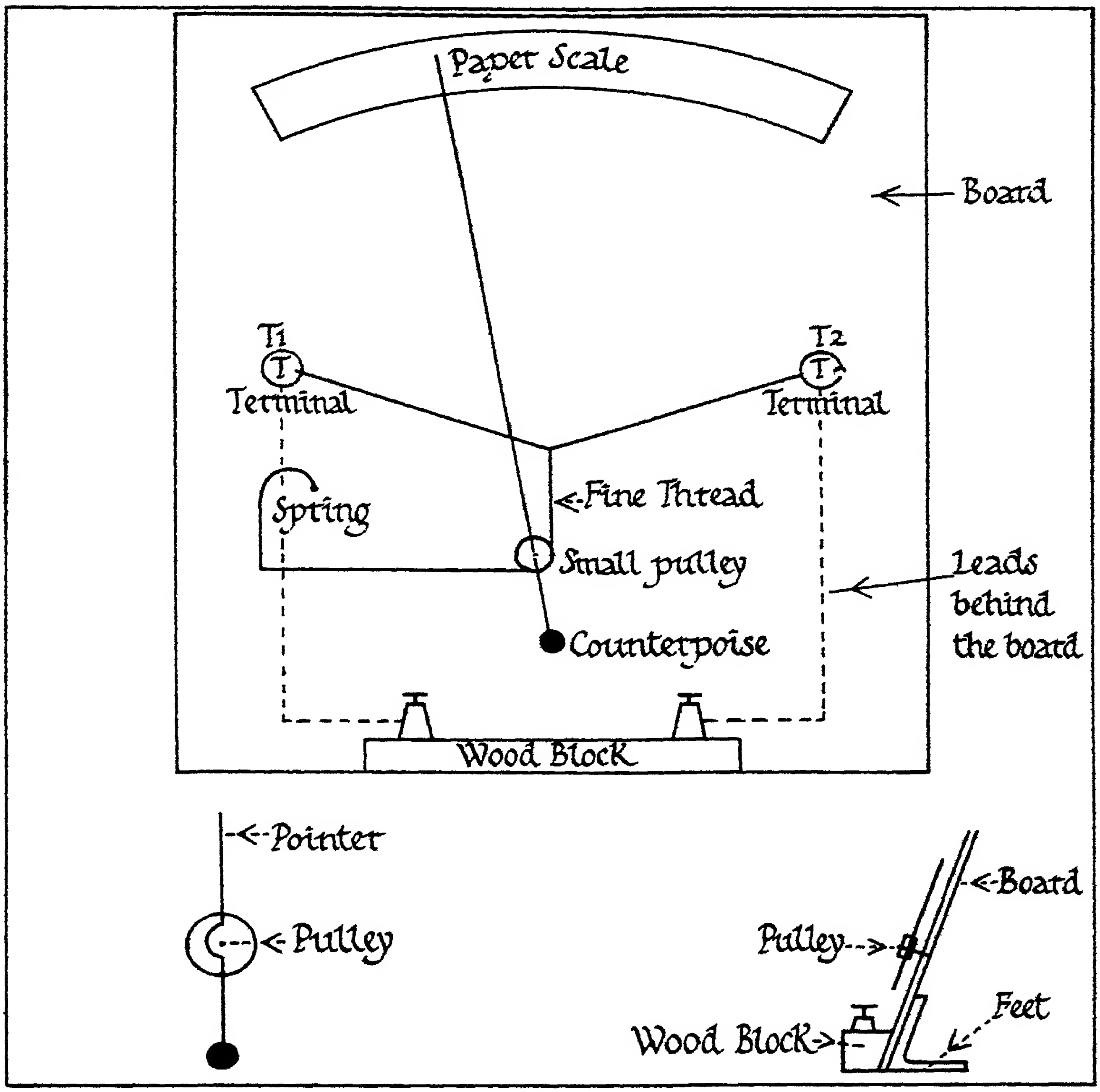
In the following pages we shall be finding out more about the behaviour of electricity and there are several models that you will have to make. None of them is very difficult, and you will learn a lot by making them and getting them to work. Here as in several cases in the past, it will be better if you work in small groups of two or three.

Look at the diagram. The board can be of thin wood or any similar material as long as it is an insulator. It is made to stand by means of a pair of "feet" of brass strip, bolted on. In the front there is a wooden block drilled to take a pair of terminals. Two other terminals, T1 and T2, are fixed to the board near to the centre, and these will take the wire that is heated by the current. A small pulley is attached by means of an axle to the board (a small Meccano pulley will do very well). To this pulley is attached a longer pointer as shown. A long pointer magnifies any movement and a small piece of lead can be attached to the shorter end as a counterpoise. If the pointer is of thick copper wire it can be soldered on to the pulley. A piece of fine thread is joined to the centre of the wire between the terminals T1 and T2 and passes round the pulley carrying the pointer and then to the piece of watch spring which is fastened to the board. The two pairs of terminals are wired up so that the wires are behind the board. Draw a paper scale as shown and mark it off in equal divisions. When this is all assembled, adjust the spring so that the thread is taut and the pointer is at one end of the scale. When a current is passed, the wire heats up and expands, and since the ends are fixed, it sags in the middle. The thread attached here is kept taut by the spring, as it does so the pulley and the pointer turn. The greater the current the greater the sag of the wire, and the more the pointer moves.

—BY ITS HEATING EFFECT

This instrument is called a "hot wire" ammeter, and you can "calibrate" it by means of an ordinary ammeter. When you do this do you find that the scale is uniform? Can you offer an explanation of what you find ?

What would you consider to be the chief sources of error in this instrument? Can they be avoided?



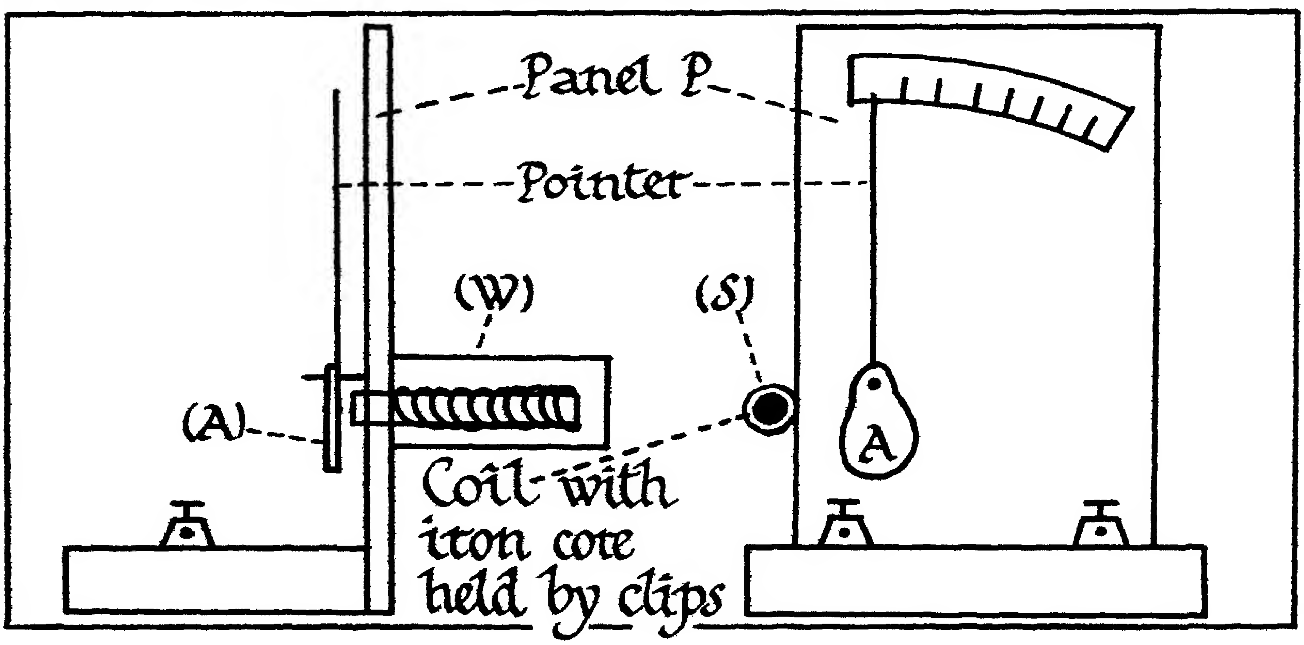
MEASURING A CURRENT—

THE magnetic effect of a current is the basis of many instruments and machines, and it can be shown quite easily. First of all we have already seen that we can use a solenoid for making a magnet. When a piece of steel was placed inside a solenoid and a current passed, the steel was magnetised. What happens if, instead of a steel rod such as a knitting needle, a piece of soft iron is used? Does the iron become magnetised when a current flows through the wire? Does it retain its magnetism when the current is switched off? Try it and see.

Now instead of having the iron inside the solenoid when the current is switched on, have a piece of iron wire just outside, and in line with the coil. What happens when there is a current passing?

Here are two simple instruments that you can make and both of them rely on the effect of a solenoid on a piece of soft iron.

A solenoid (S) or wire wound on a cardboard tube such as a piece of a thermometer case, is held on to the side of a strip of wood (W), fixed to the front panel (P), by means of a clip. The ends of the coil are wired to two terminals screwed to the wood block. The moving arm is cut out of a piece of thin tin-plate (A). A thin piece of wire is soldered to the end so that it acts as a pointer, and a hole is made in the tin-plate so that it can pivot about a pin as in the diagram. A paper scale can be pasted on to the end of the block. The core of the solenoid is an iron bolt that just fits inside after the bolt-head has

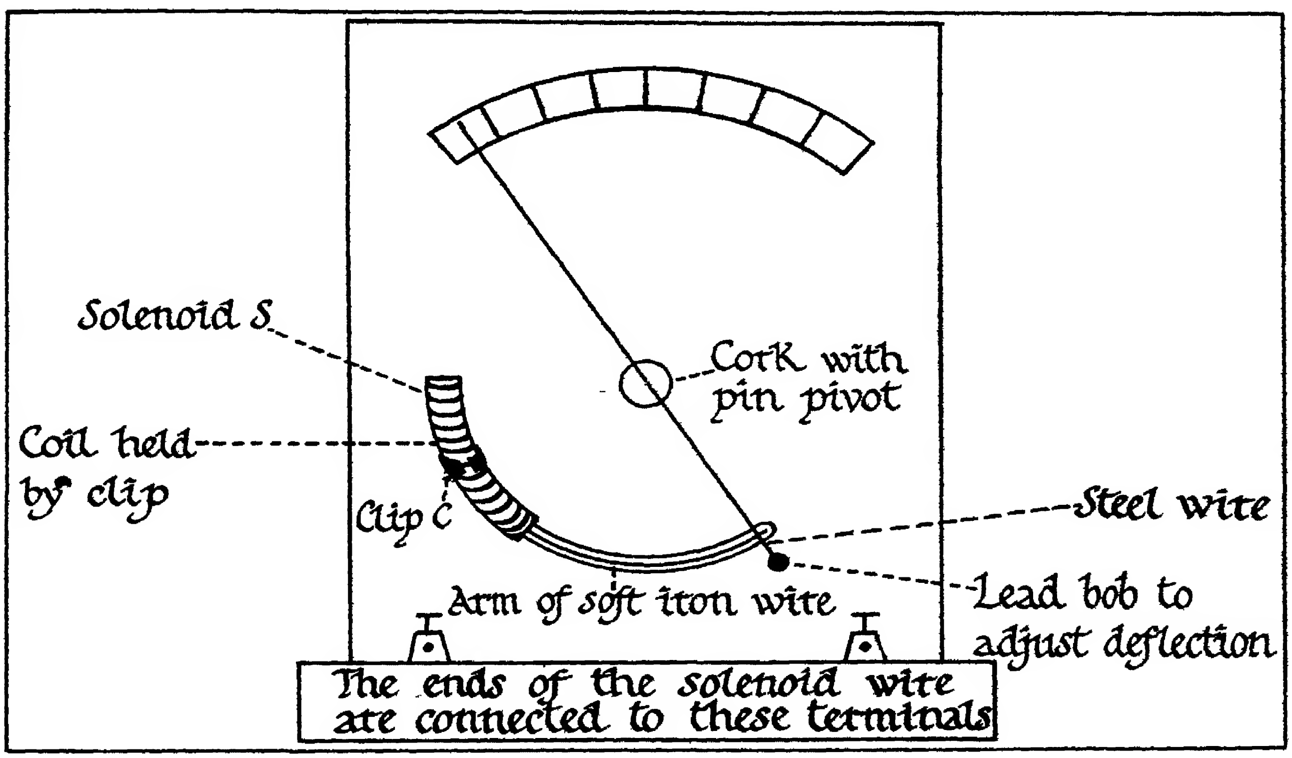


—BY ITS MAGNETIC EFFECT

been cut off. When you have made this instrument, find out if the magnetic attraction of the core, shown by the deflection on the scale, varies with the current, by using a variable resistance in the circuit.

The other instrument is a little more difficult to make, but well worth your while trying. If you look at the diagram you will see that a curved solenoid (S) is needed. This can be made from a curved piece of copper tubing about an inch and a half long, and about a quarter of an inch in diameter. Three layers of fine copper wire are wound on. This coil is then mounted on a piece of wood as shown by means of a clip (C). The arm is made of several pieces of soft iron wire twisted together and attached to a pointer, such as a piece of steel wire or a thin knitting needle. The movement is fixed to the board through a cork which has a pin through it. An alternative method is to attach the needle to a small pulley that can pivot about a metal rod fixed to the wood. The amount of deflection for a given current can be adjusted by means of a small piece of lead which is fixed to the bottom of the needle.

These two instruments show how we can measure a current by using the magnetic effect of a solenoid on a piece of iron.

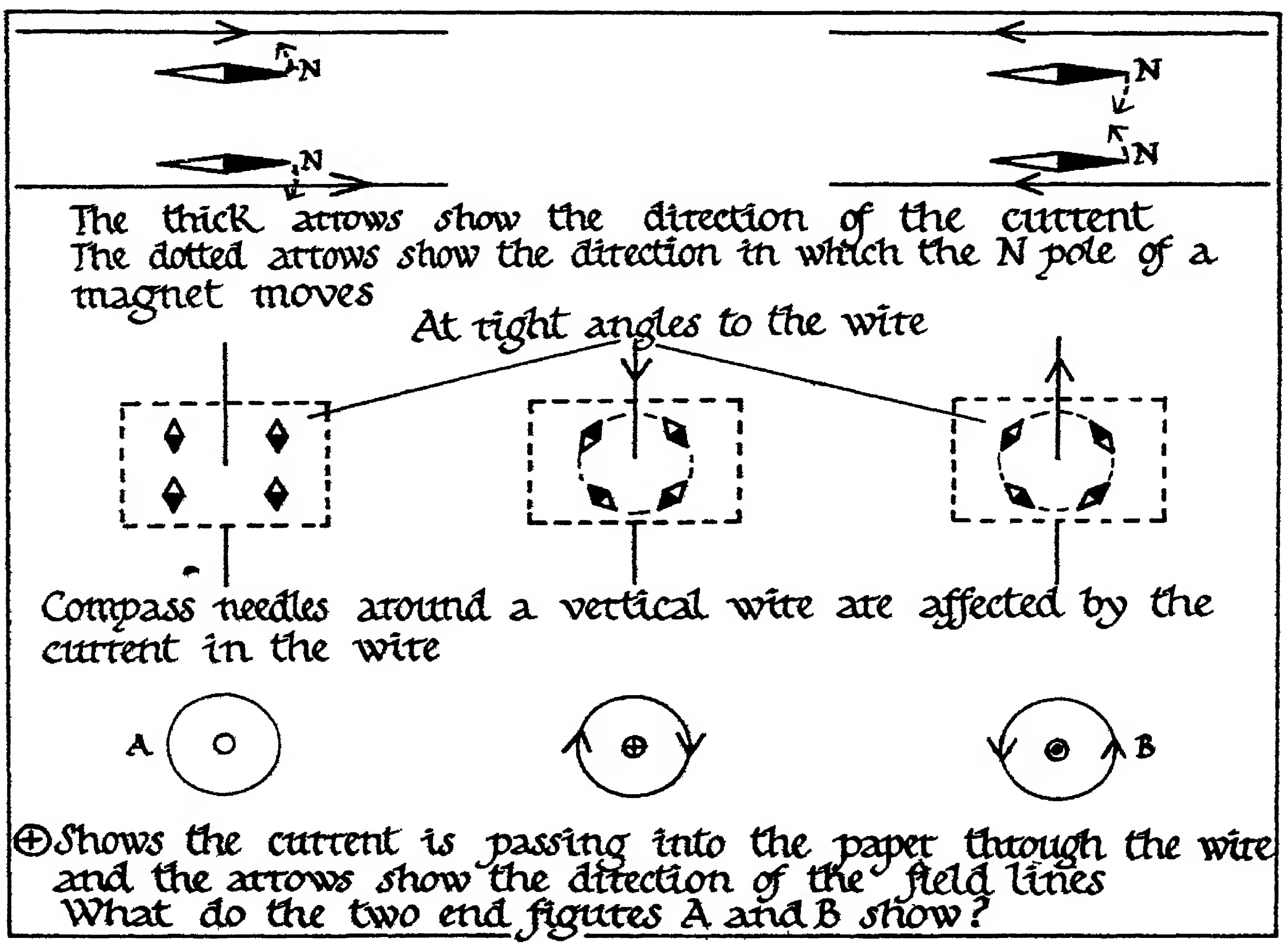


MAGNETS, CURRENTS—

WHEN a magnet is brought near to a compass needle, the needle is deflected, and the direction in which it turns depends on which end of the magnet is nearer it.

In the same way, a compass needle is deflected by an electric current passing near to it. As you saw earlier on, the direction that the needle is deflected by the same current depends on the direction of the current, and whether the needle is above or below the wire carrying the current. With a fairly small current, the deflection is small. It can be increased, though, by having many turns of wire round the needle instead of using a straight wire.

Instead of having the wire in a horizontal direction, it can be placed vertically with compass needles around the wire, and the needles will again be affected, and again the deflection will depend on the direction of the current. Look at the next set of diagrams. The behaviour of the needle can be summed up as the "Right-Hand Rule" which says that if



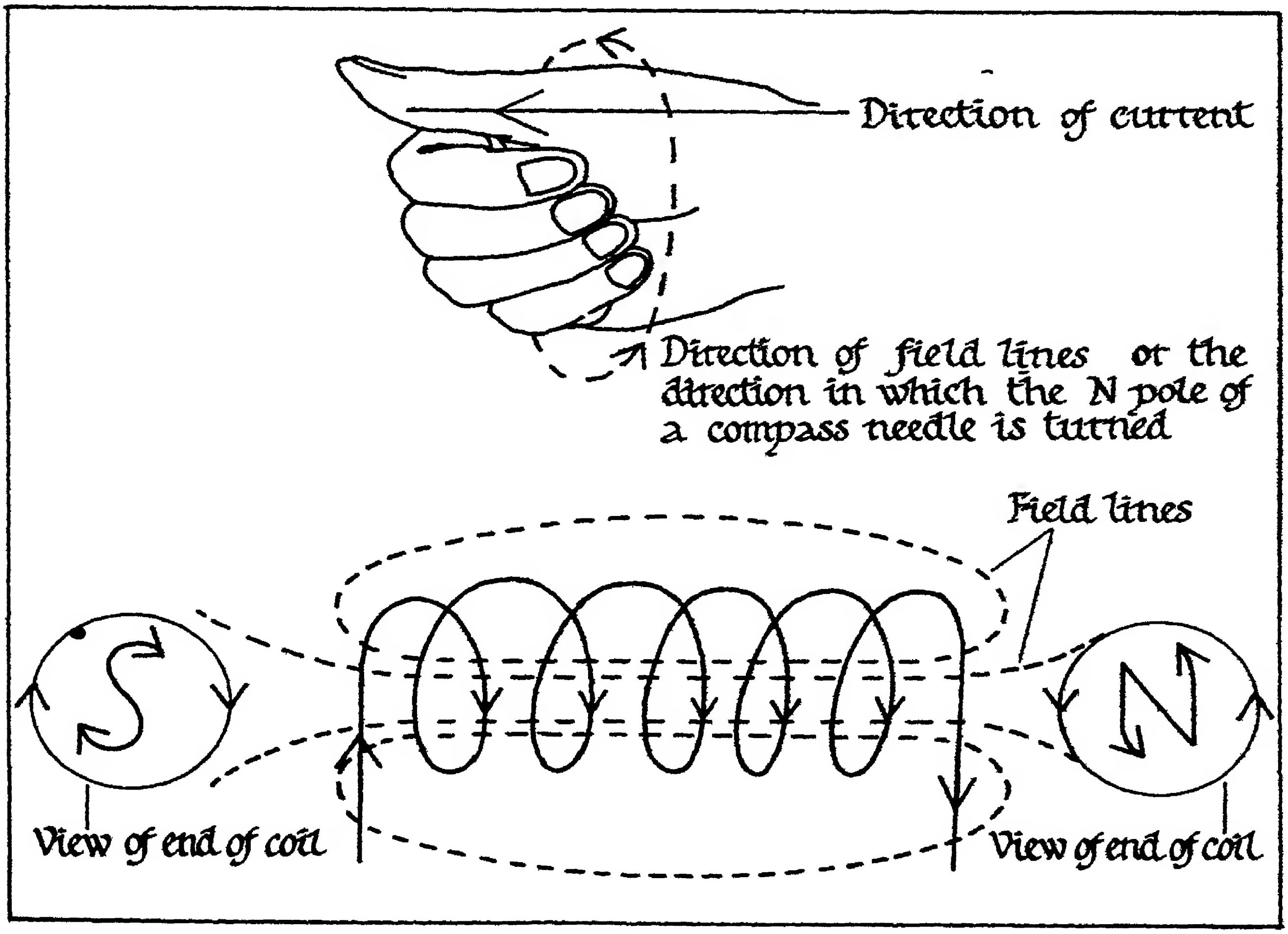
—AND THE RIGHT-HAND RULE

the thumb of the right hand is in the direction of the current, then the curled fingers show the direction in which the north pole of the compass needle moves. This is sometimes known as the "Corkscrew Rule". Why?

The effect is increased by having a large number of turns of wire, or a solenoid, where each turn of wire reinforces the effect of the others. Then a fairly uniform magnetic field is produced along the axis of the solenoid. As with a magnet, the solenoid has both a north and a south pole, as you can see in the diagram.

Make a small coil of cotton-covered copper wire. Support it in a vertical position and hold a compass needle at the centre. Notice the effect on the needle, when a current is passed. Alter the position of the needle and also reverse the current.

Now, with a current passing through the suspended coil, bring up first the north pole, and then the south pole of a magnet. Reverse the current and repeat this. Can you explain what happens and why?

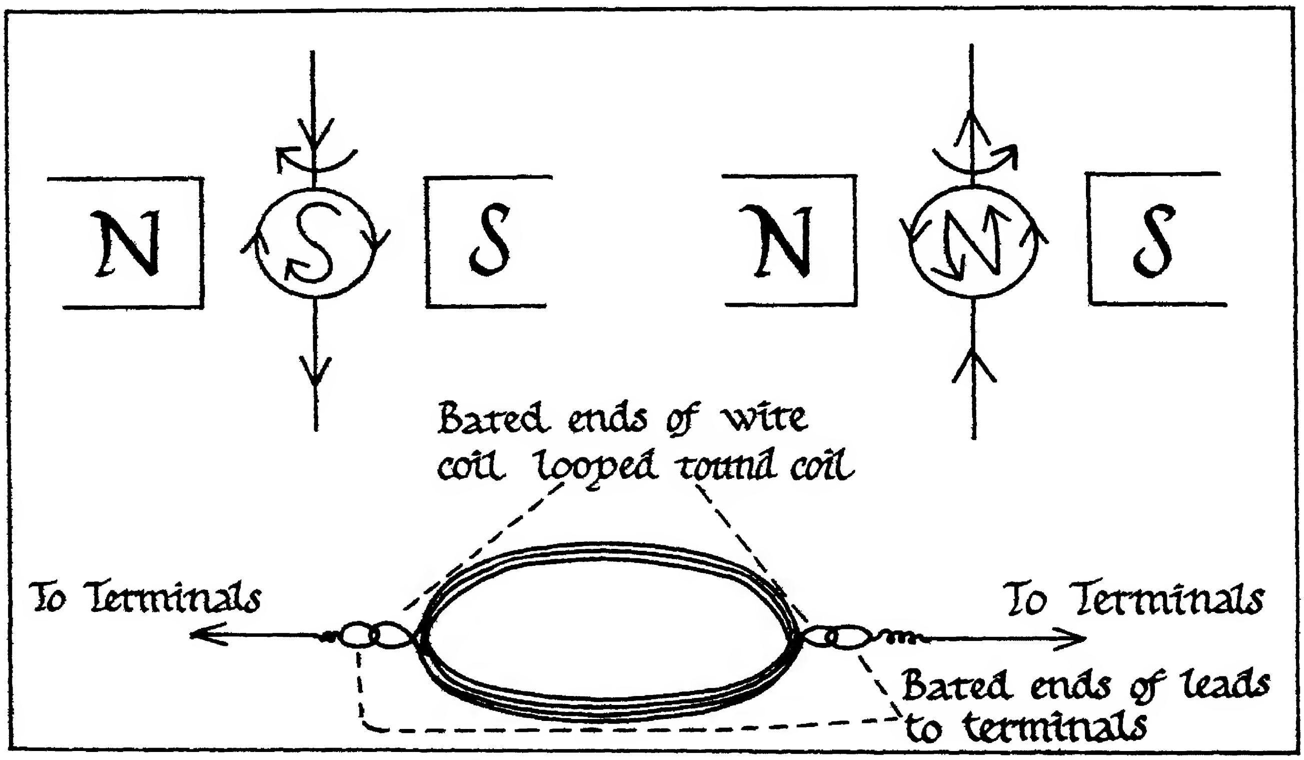


A MOVING COIL—

A COIL, through which a current is passing, will tend to turn when it is in a magnetic field. This field can be that between two poles of a magnet. The amount of turning depends on several things. Can you think of the things that can be altered to vary the amount of turning?

We have seen how the heating properties of a current, as also the magnetic properties, can be used to measure a current. The effect of a magnetic field on a coil carrying a current can be used as a measure too. Such an instrument is called a "moving coil" galvanometer. Again we will make a model which, although it will not be very accurate, will show the principle of the instrument.

Make a coil of wire, having about twenty to thirty turns of fine cotton-covered copper wire. The diameter of the coil should be about one inch. You can do this using a large test-tube to wind the wire around. The last turn is lapped round to bind the rest of the coil, and the ends of the wire must be bared and looped as shown. Now slightly flatten the coil. To a small baseboard fit two wooden terminal blocks. They can be screwed or glued to the board. They should be about an inch and a half high. The bared ends of the coil are looped to wires,



—WILL MEASURE A CURRENT

the bared ends of which are in turn joined to the terminals. These leads to the terminals are drawn fairly taut, so that the coil may rotate.

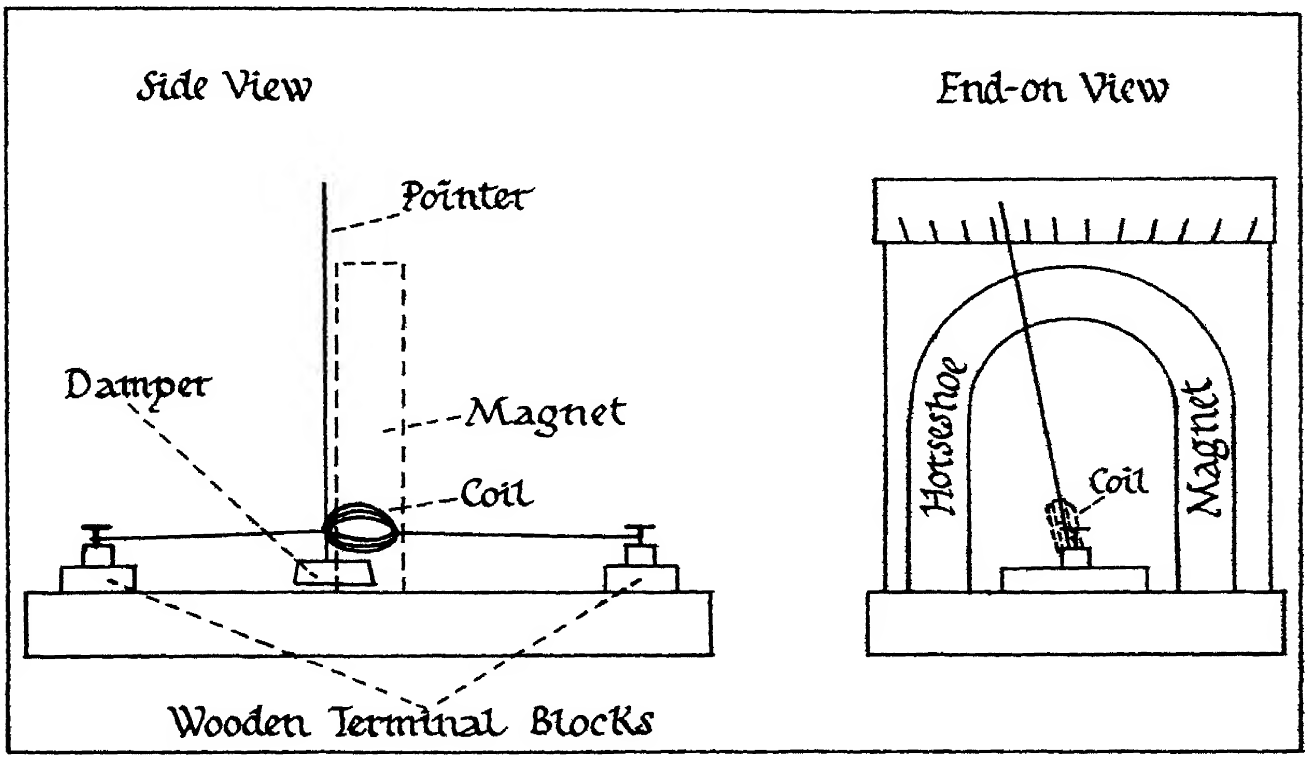
An alternative coil can be made by using even finer wire. In this case, separate leads are not needed, but the ends of the coil themselves may be taken to the terminals after first baring the wire. In this case, smaller currents must be used. Why do you think this is so?

To the coil itself, a pointer is attached, made from a piece of copper wire. Since the coil and, therefore, the pointer will not come to rest straight away, a "damper" is made from a small piece of paper as shown and attached to the pointer. By this means the pointer will come to rest more quickly. A horseshoe magnet placed as in the diagram will provide the field in which your coil will turn.

All you need when you have reached this stage is a scale and this you can fix using small strips of wood to the side of the baseboard.

What do you consider to be the most serious sources of error?

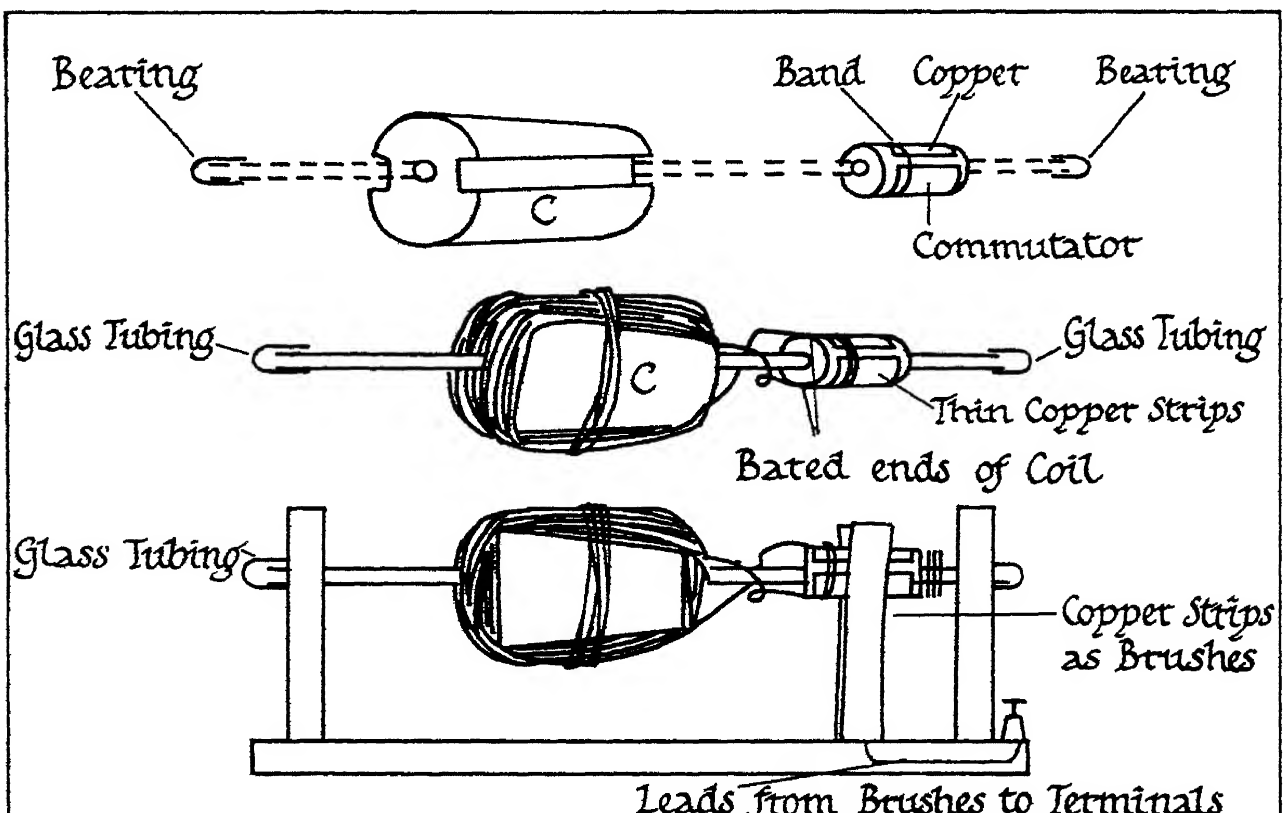
We have made two instruments for measuring an electric current, one depending on the heating effect and the other on the magnetic effect. Should they give the same reading for the same current after calibration?



AN ELECTRIC MOTOR—

THE electric motor works on the same principle as the moving coil galvanometer in that a coil carrying a current can turn in a magnetic field. In the case of the motor, however, the rotation is continuous. Here is a simple model of an electric motor that you can make for yourselves and so see how it works.

Cut two grooves down the sides of a cork (C), as in the diagram, and then push a piece of knitting needle through the centre. Wind about thirty to forty turns of wire round the cork for the coil. This part is the "armature". The "commutator" can be made by pushing a small cork or rubber bung on to the needle at one end. Secure two curved pieces of thin copper on to the bung by means of an elastic band. When the two pieces of copper are in place there should be a small gap between them. Bare the ends of the wire from the coil. These ends must be held, one on each side, between each piece of copper and the rubber bung. For the bearings use two rounded pieces of glass tubing set into pieces of wood at the end of the baseboard. For



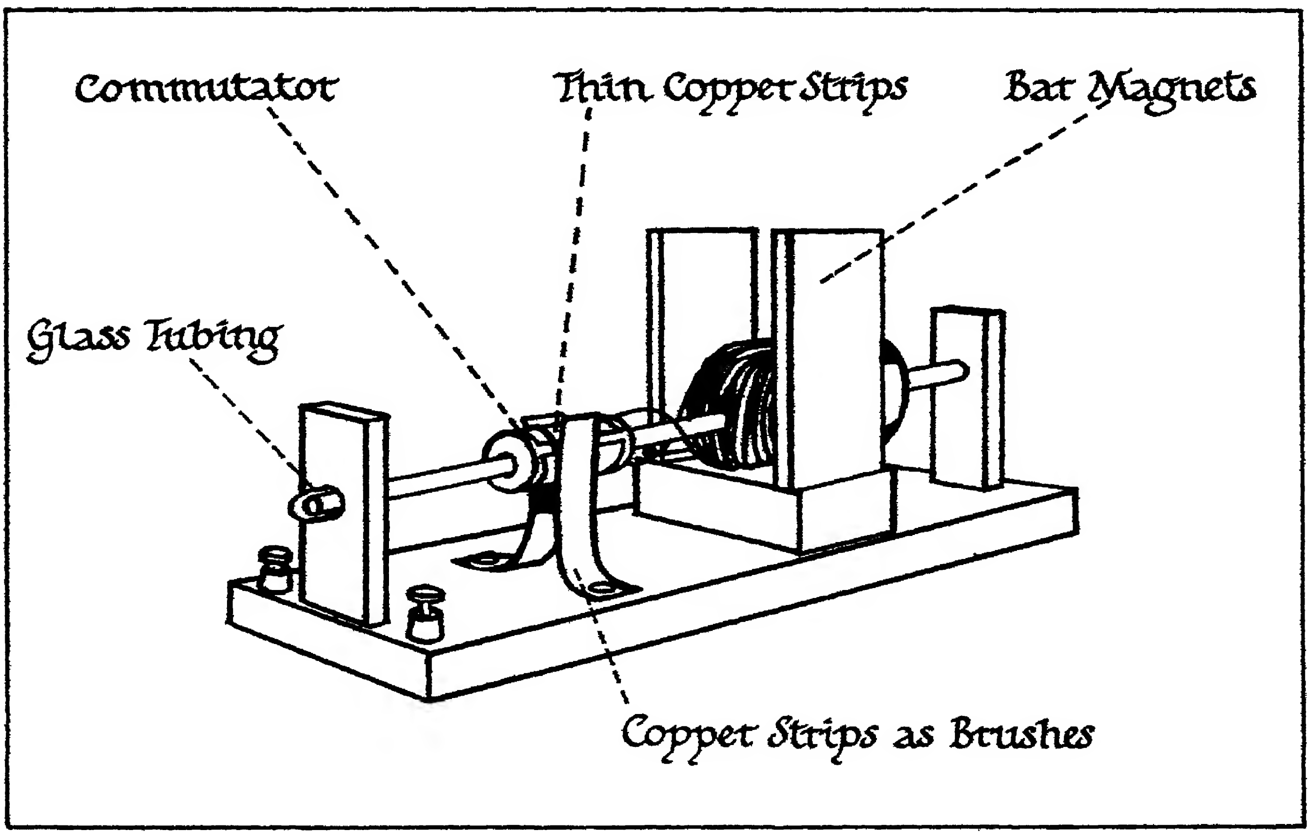
—USES A ROTATING COIL

"brushes" use two strips of copper fixed to the board, and from these "brushes" leads are taken to two terminals. The magnetic field can be provided by two permanent magnets.

You will see that the great difference between this motor and the moving coil galvanometer is that the direction of the current round the coil is changed every half turn of the coil by means of a commutator. The diagrams will help you to follow this. Such a motor will not run very smoothly. If smooth running is required, as it is in nearly all electric motors, the armature is designed to have many more coils in it. This, of course, means that the commutator as well as the wiring will be much more complicated.

Find out what you can about the construction of electric motors, especially why the coils are wound on to soft iron, and what type of magnets are used to provide the field.

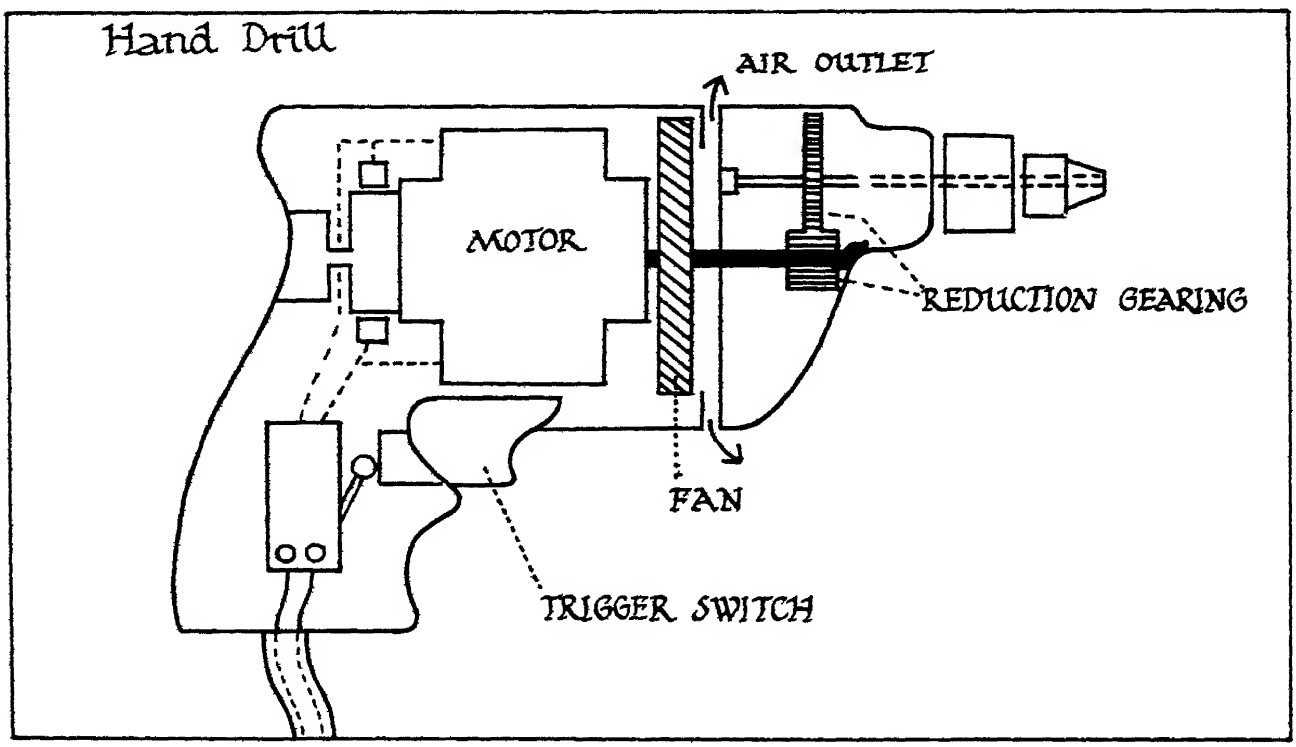
Why does the commutator make rotation continuous? What is the effect of reversing the current in the coil?



THE SMALL MOTOR—

THE electric motor has many uses in small tools and instruments. These motors are very much more efficient than the one that you made, although the principle remains the same.

The electric hand-drill uses an electric motor, and in this case it is part of the instrument. Because electric motors are more efficient when they run at high speed, the motor is geared down from a high to a more suitable speed for drilling. These gears are fitted into the casing of the motor. The supply of electricity from the mains is brought into the "butt" of the drill, and the tool is earthed through the cable to prevent a shock should there be a short. The switch is a trigger switch which can be conveniently worked by the forefinger. Such an instrument as this, which may be used for long periods at a time, will become heated. To prevent this, a small fan is fitted, as shown in the diagram. Air is drawn through holes in the casing, passes through the filters and, after circulating through the instrument round the motor, passes out again as shown. The casing is made of a light alloy, and as very efficient, though small, electric motors are available today, a very powerful and handy instrument can be built.



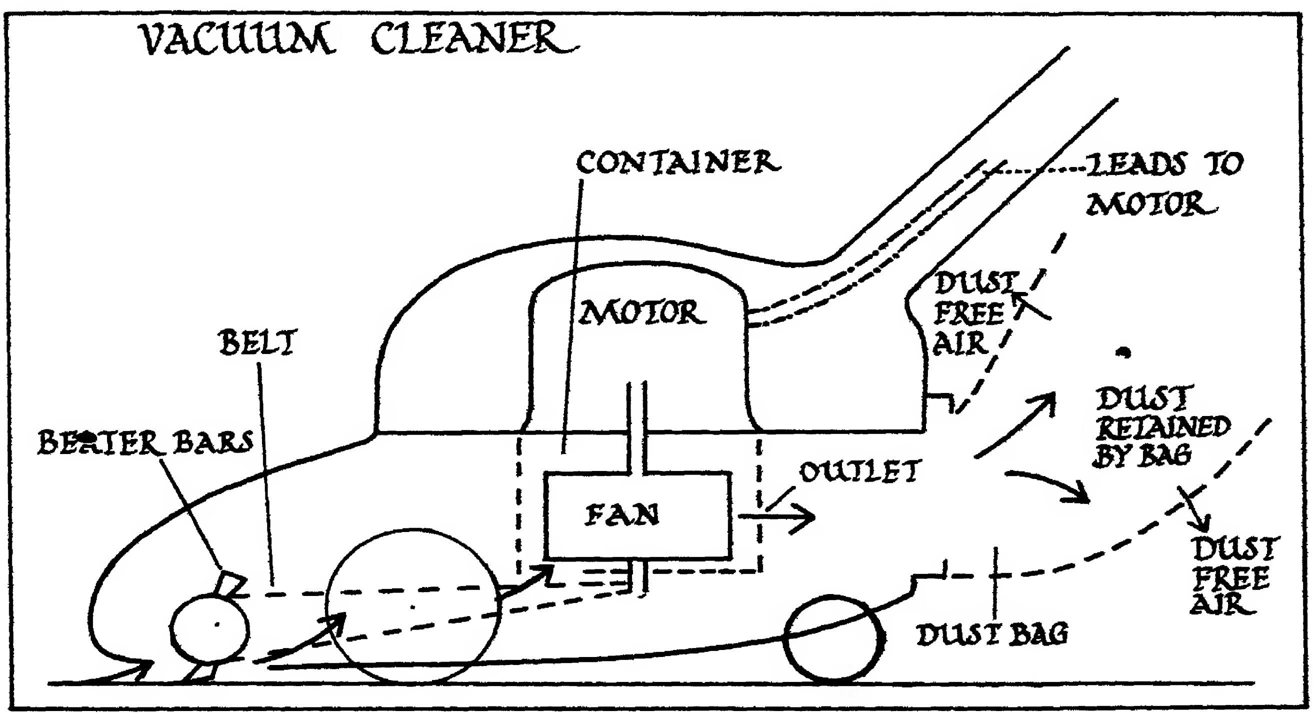
—LIGHTENS OUR WORK

The vacuum cleaner has nothing to do with a vacuum. It makes use of a draught. An electric motor turns a large fan which draws air through the cleaner, and at the same time turns a brush by means of a rubber drive. The brush and the suction raises the carpet and the pile so that the dust is freed. The air carries the freed dust with it into the container. This has no outlet except through the dust bag. The dusty air has to pass through the fan compartment and as it is whirled round it flies outwards and leaves the container by the outlet into the dust bag. Here the dust is trapped by the close material of the bag, whilst the air alone passes through the material.

At the hairdressers you have probably seen the electric clippers in use, and the electric hair dryer. Both of these have small electric motors. What other instruments can you think of that have small electric motors in them?

All the instruments and tools mentioned here, are only available because it is possible to make very small electric motors that can be built into the tool or instrument.

Some windscreen wipers are driven by small electric motors. Find out how they work.

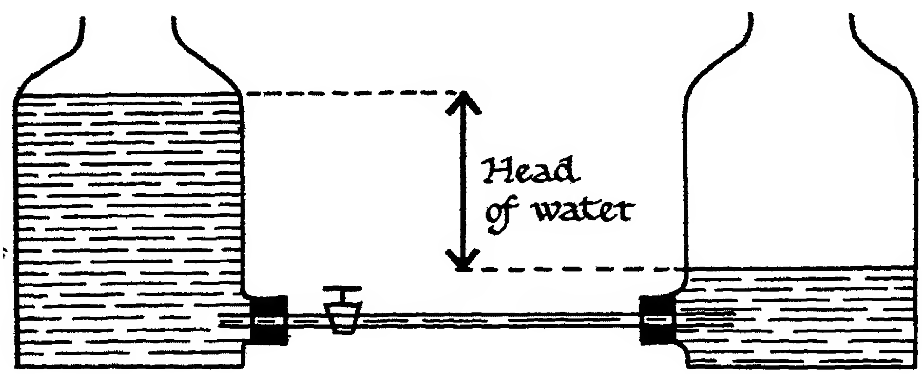


THE FLOW OF WATER—

IN everything electrical that you have considered so far there has been an electric circuit. It is often easier to understand the working of it if you compare it with a water circuit. This is especially useful when you are thinking of electrical "units". The simple piece of apparatus shown here is easy to fit up and you can see it in use for yourselves, but the more complicated one needs things that are not available to you.

The first piece of apparatus consists of two "aspirators" connected by a piece of glass tubing, with a tap fitted in. When the two aspirators are partly filled with water, of course no water will flow until the tap is opened. Opening the tap allows water to flow from one aspirator to the other as long as there is a difference in the water levels. This difference is sometimes called the "head of water". When will the flow be faster, when the head of water is small or large? You will see that as the levels of water become nearly the same, the flow of the water slows down, and finally stops. The greater the head of water, or pressure, the faster the flow, and consequently the greater the quantity of water flowing in a certain length of time.

In what other way can the flow be varied? Replace the glass tubing with other lengths, one wider and one narrower than the first piece used. Through which is the flow (*a*) faster, and (*b*) slower?



The flow will depend on 1. Pressure or head of water
2. Length of tube
3. Diameter of tube

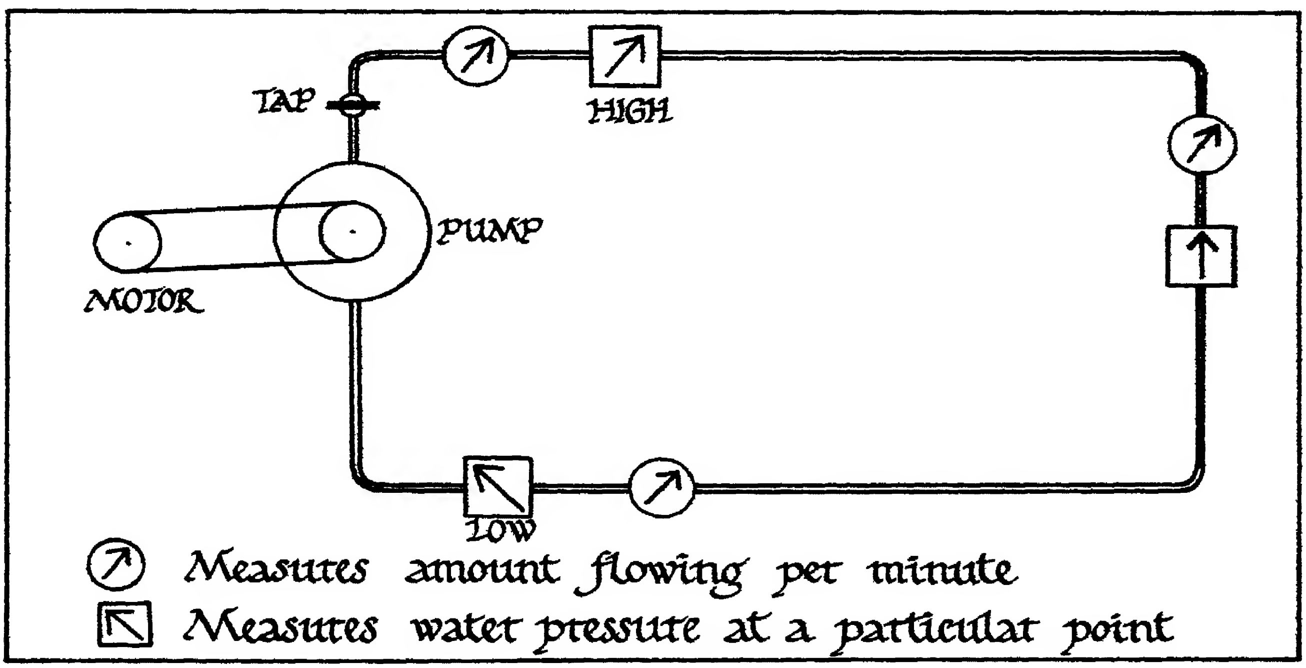
—THROUGH A CIRCUIT

Remember that the head of water or pressure must be the same to start with each time you do the experiment. Now vary the lengths of the tubing. What do you find?

Even with the tap closed, although the water does not flow, there is still the tendency for it to flow. Another way in which the flow can be controlled is to use the tap, for partly closing it will reduce the flow.

If we want a continous flow, the head of water must be maintained; in other words the difference in levels must be maintained. This can be done with a pump as in the next diagram. Here the water is going round a "closed circuit". The total flow of water, in say gallons per hour, will be the same all the way round the circuit. There is no accumulation, or shortage, anywhere. The amount of water flowing in this circuit will depend again on the pressure of the pump, the length of the pipe, and the diameter of the pipe. It can be controlled by the tap. Will the flow be faster, or slower, if a second pipe is run parallel to the first one and connected up?

When water is obtained from a tap, the pressure is decided by the head of water and we cannot control this. The amount of water flowing from a tap (which we can control) depends on the pressure of water in the pipe and the size of the pipe (neither which we can control).



THE FLOW OF ELECTRICITY—

IN an electrical circuit, the source of electricity corresponds to our water pump. If it is a household circuit, then the pump will be the generator at the power station and this will maintain the difference in electrical levels, that is, in the electric pressure between the leads to and from the house. There will be a pressure difference between the terminals in any plug sockets. The difference in electrical pressure is called the "potential difference".

Batteries, accumulators and the mains supply, all give a potential difference which, like the pressure of the mains water supply, we cannot alter. In our water circuit it was possible to control the flow of water by altering certain things in the circuit. Can you suggest how we might control the flow of electricity in our electrical circuit?

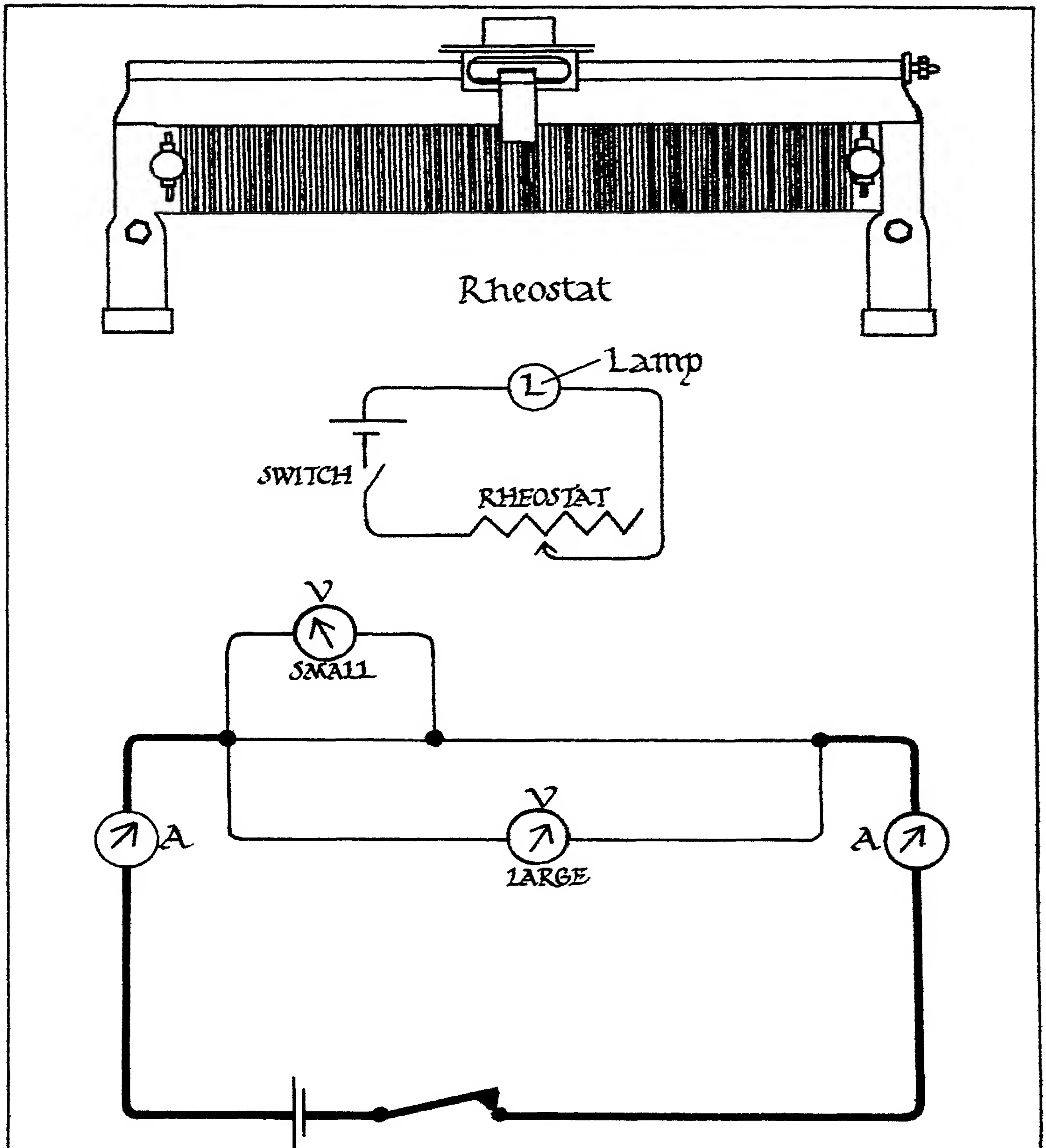
We can alter the lengths of wire in the circuit and alter the thickness of the wires as well, but it is more convenient to use a "rheostat", or variable resistance. This is essentially a length of wire wound round a tube, with a slide. By moving this slide the length of wire brought into use can be altered. Using either a mains supply to light a lamp with a variable resistance in the circuit or a circuit for lighting a torch bulb from a small battery, vary the length and the diameter of the wire by using rheostats of different values. Does the brightness of the lamp vary as the resistance is altered? Can you say in which ways the water circuit and the electric circuit are not comparable? As in the water circuit, the flow of electricity is the same all the way round the circuit. There will be no accumulation or shortage anywhere. As in the water circuit the fall in pressure or the potential difference between two points will depend on the distance between those points.

Electricity has its own system of measurement. Here are some of them.

Unit of electric current	Ampere
Unit of pressure or potential difference	Volt
Unit of resistance	Ohm
Unit of electric power	Watt

When a current of I amps is maintained by a potential difference or pressure of E volts, the power or rate of working is $E \times I$ watts. Everyone who has to pay for electricity is concerned with killowatt-hours. Find out what these are.

—THROUGH A CIRCUIT



A Ammeter measures the current flowing

V Voltmeter measures the pressure or potential difference

THE ELECTRIC LAMP—

THE three electrical units, ohms, volts, and amperes (or amps) are connected, for it is found that if a potential difference of E volts sends a current of I amps through a conductor, the resistance of the conductor is R ohms, where:

$$E \text{ (volts.)} = I \text{ (amps.)} \times R \text{ (ohms.)}$$

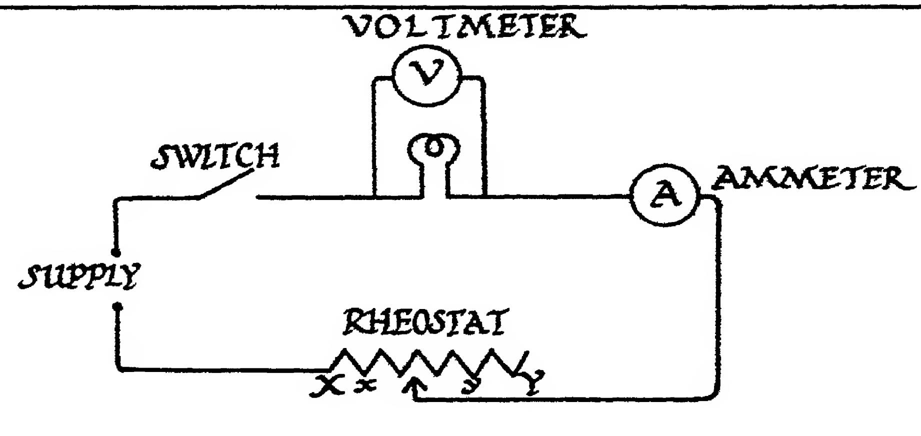
This relationship is sometimes called Ohm's law. By means of this relationship we can measure the resistance of an electric lamp. The diagram shows how the circuit is wired. The supply can come from the mains, using an electric lamp or from an accumulator using a car bulb. You must be careful to use suitable instruments and rheostats. Why do you think that the voltmeter is connected across the lamp and is not in the circuit with the ammeter? Do we need the pressure across the lamp or across the supply? Are they the same? Start with the slide on the rheostat at the end Y so that the whole of the resistance is in the circuit. Are the ammeter and voltmeter readings high or low? Vary the position of the slide and notice if the readings vary. Does the brightness of the lamp alter? Draw up a table of your results and work out the resistance of the lamp for each position of the slide. Then the value you obtain for the resistance will be the resistance for each particular brightness. When the slide is at the end X of the rheostat the reading of the ammeter is the normal working current of the lamp, and the potential difference across it will be the potential difference of the supply. What is the resistance of the lamp under these conditions?

Repeat this with other lamps of different values.

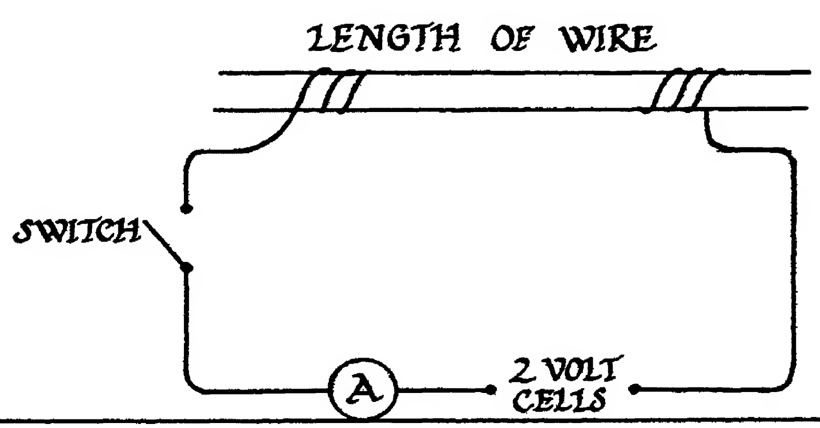
How does the resistance of the filament vary with the temperature of the filament?

Here is another experiment that illustrates Ohm's law. The circuit is shown in the lower diagram, and it includes a length of seven or eight yards of 20 gauge Eureka wire. The advantage of this particular wire is that its resistance does not increase very much when it is warmed. The current produced by the 2 volt cell is measured by the ammeter. Repeat this using first two such cells in series, and then three, and finally four in series. Calculate the resistance of the wire each time. Do you think the increased length of path through the extra cells has any effect on the result?

—AND OHM'S LAW



POSITION OF SLIDE	AMMETER READING A	VOLTMETER READING V	RESISTANCE(V/A)	BRIGHTNESS OF LAMP
Y				
y				
x				
X				



THICK WIRES AND THIN

THE mains-supply cables which come into your electricity meter at home are very much thicker than the wires used for carrying the current from the meter to an electric lamp or to a radio set. Why is this so? The current through the mains is a large one, while the current needed for many household appliances is much smaller. Just as in our water circuit we could control the amount of water flowing by altering the diameter of the pipes, so we can alter the amount of electricity current flowing in a circuit by altering the resistance of the wire by either increasing or decreasing its diameter. We can use the following relationship:

Volts ("pressure") = Amps (current) × Ohms (resistance).

This will help us to answer the questions under the first set of diagrams and to fill in the missing figures. Copy them out into your record books. Do not mark this book.

You will see that if the voltage remains the same, when we halve the resistance the current is doubled, while when the resistance is doubled the current is halved. What happens when the voltage is varied but the resistance stays the same?

The second set of diagrams again illustrate the relationship between the voltage, the current and the resistance.

We have another relationship:

Rate of heating is proportional to current × current × resistance.

250 V	? (ohms)	25 A	125 V	25 OHMS	? amps
250 V	? (ohms)	50 A	250 V	25 OHMS	? amps
250 V	? (ohms)	$12\frac{1}{2}$ A	375 V	25 OHMS	? amps
250 V	? (ohms)	10 A	500 V	25 OHMS.	? amps

Which will be

a) The thickest wire?

b) The thinnest wire?

Through which will there be

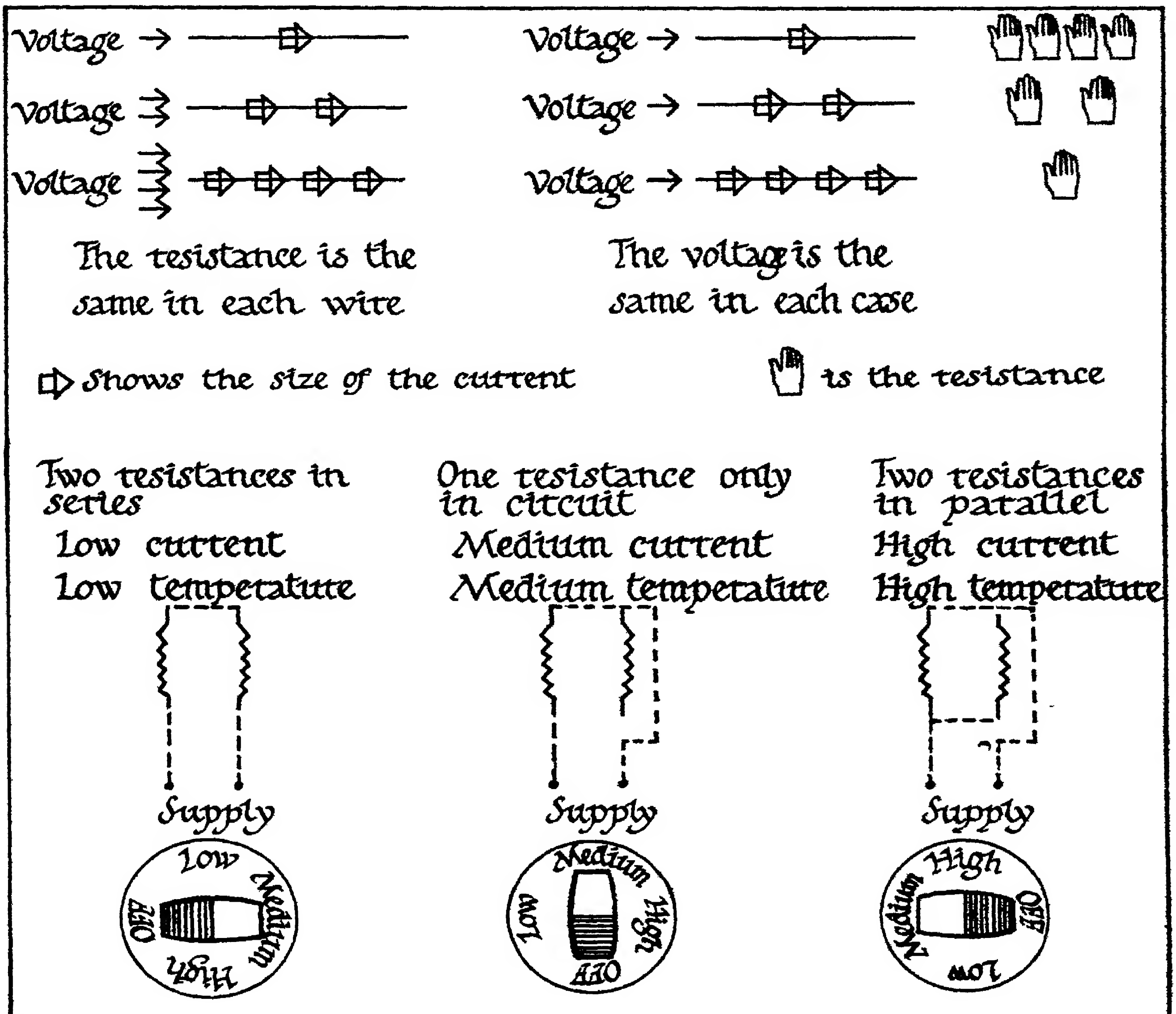
a) The largest current?

b) The smallest current?

SERIES AND PARALLEL

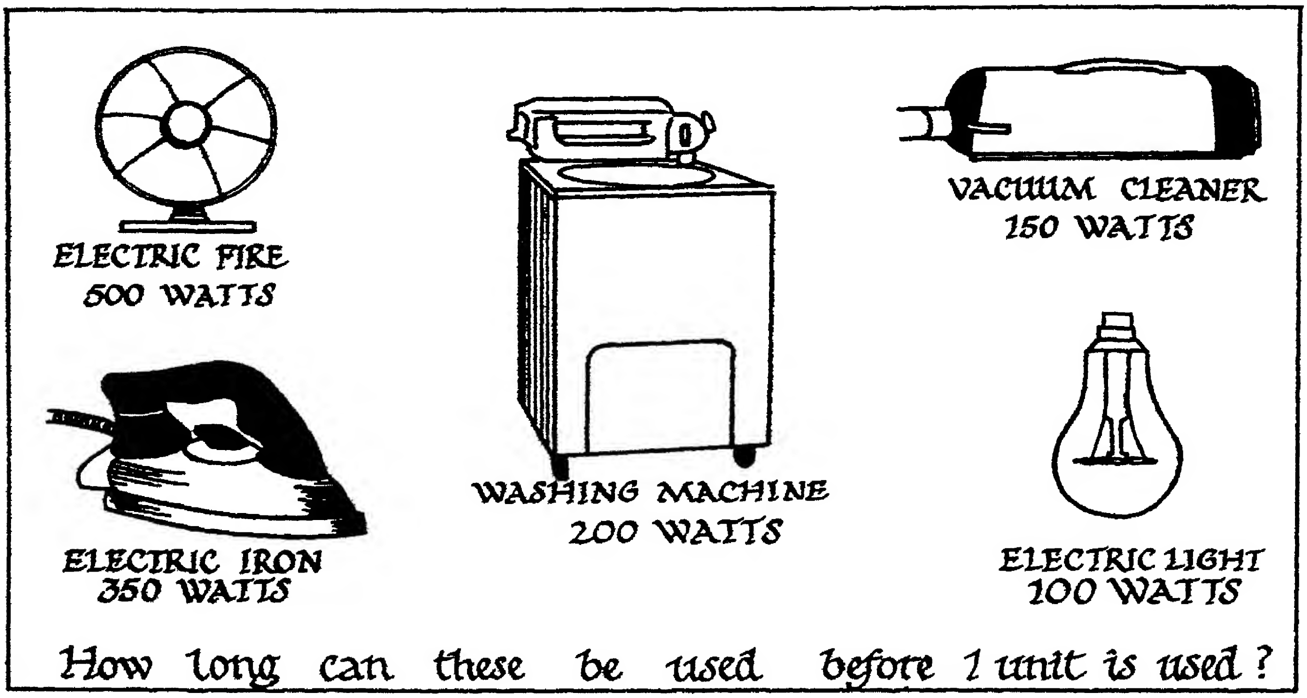
The third set of diagrams show you how the current and resistance in a circuit can be varied while the voltage is kept constant. This will give different rates of heating. By using two resistances, either in series or in parallel, or by using one resistance only, the total resistance and therefore the current can be varied. By this means the rate of heating is varied in the electric hot-plate. The circuit is simply altered by the means of a switch which connects resistances in different ways.

Why is the wiring of electric lights always separate from the wiring for "power" points?



The dotted lines show the connections in use to the elements

THE COST OF THE CURRENT—

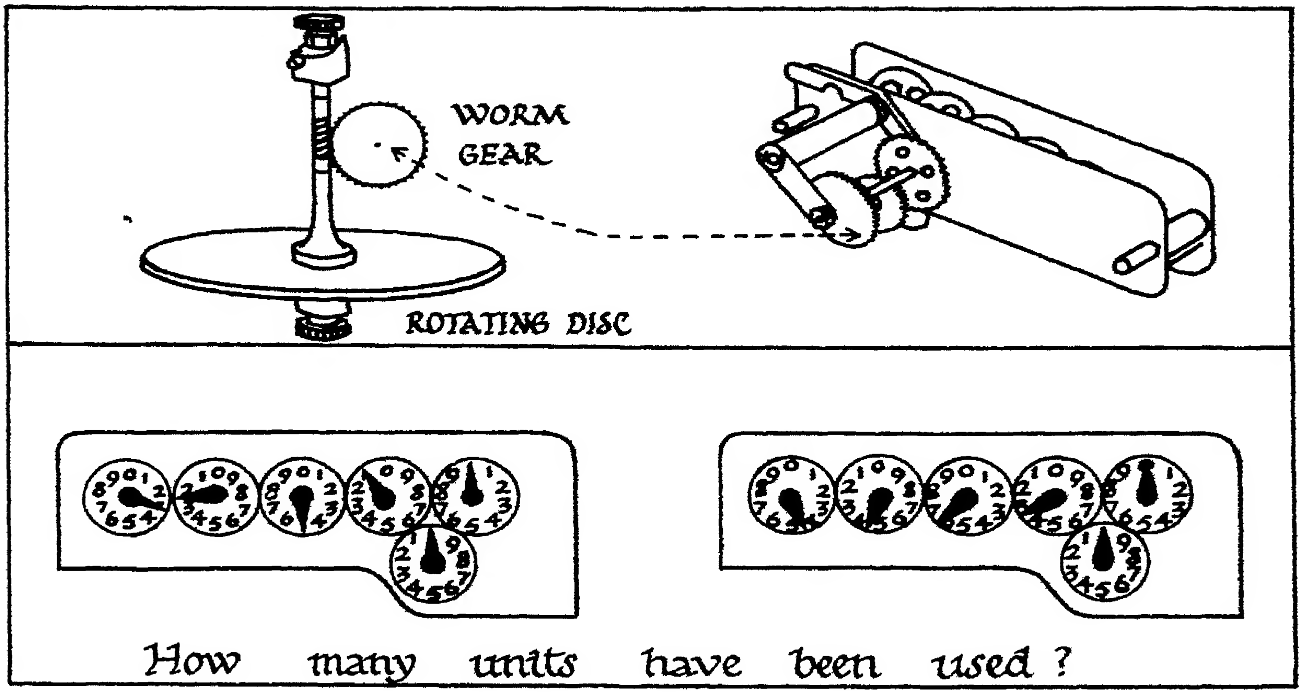


IF you use electricity in your home you have probably heard your father talk about "units" of electricity when either he has just received an electricity bill, or when lights have been carelessly left on. What does he mean by "units" in this case? We have seen that the power or rate of working is found by multiplying the voltage by the current in amperes that the instrument or appliance is using. This power is measured in watts. Since you pay for the amount of power used time will have to enter into the calculation. In this way, the electrical energy used is measured in watt-hours, that is, the number of watts used multiplied by the number of hours for which it is used. This is rather a small unit, so instead a thousand of these watt-hours are taken as the "unit" for which you are charged. In other words, the unit of electricity is a kilo-watt hour, or a thousand watt-hours.

You will see from this that an appliance that needs less power than another can be used for a longer period before it uses as much energy or units of electricity. Look at the diagrams and work out the hours each can be run before they use one unit of electricity.

The amount of energy or units of electricity used over a certain period is registered on the electricity meter. When electricity is being used, an aluminium disc in the meter is driven round and its speed is a

—AND "UNITS" OF ELECTRICITY



measure of the energy being used, or watts per hour. The more energy being used the faster it will turn. Attached to the shaft through the disc, is a worm wheel which drives a train of gears. On this train the gearing is such that each pointer rotates at only a tenth of the speed of the one before it. These pointers tell us how many units have been used.

The cost of electricity varies with the district and the purpose for which it is used. Sometimes electricity for lighting and electricity for power are charged at different rates, while sometimes the charge for each may be the same. Learn to read your electricity meter at home, and get someone to check your reading and help you to keep a record of the number of units used in your home over a period of several days. If the number of units varies a lot try to find out why. See if you can work out the cost of your electricity over this period for each day. No doubt your father will tell you how much a unit of electricity costs. Instead of using a different circuit for each type of power point, some new houses have power supplied by one circuit only, and through any point up to 13 amps. Each plug carries its own fuse suited to the appliance to which it is connected. What are the advantages of this system?

DYES AND PIGMENTS

MAN began to colour his cave drawings and his pottery, as well as decorate his body at a very early stage in his development. Prehistoric cave drawings have been discovered in France and Spain that are many thousands of years old and they were decorated with coloured earths. The early colouring matter came from two sources, pigments from the earth and dyes from plants. What is the difference between a pigment and a dye? A dye or a substance closely related to the dye must be soluble in water and be able to attach itself to the material to be dyed. There are many coloured substances that are soluble in water, but will not attach themselves permanently to material. A pigment is not soluble in water, and the material to be coloured has to be treated differently. In this case, the pigment is spread over the material in the form of very fine particles by various means. Thus our clothing is coloured by means of dyes, but our paints and crayons are coloured by pigments.

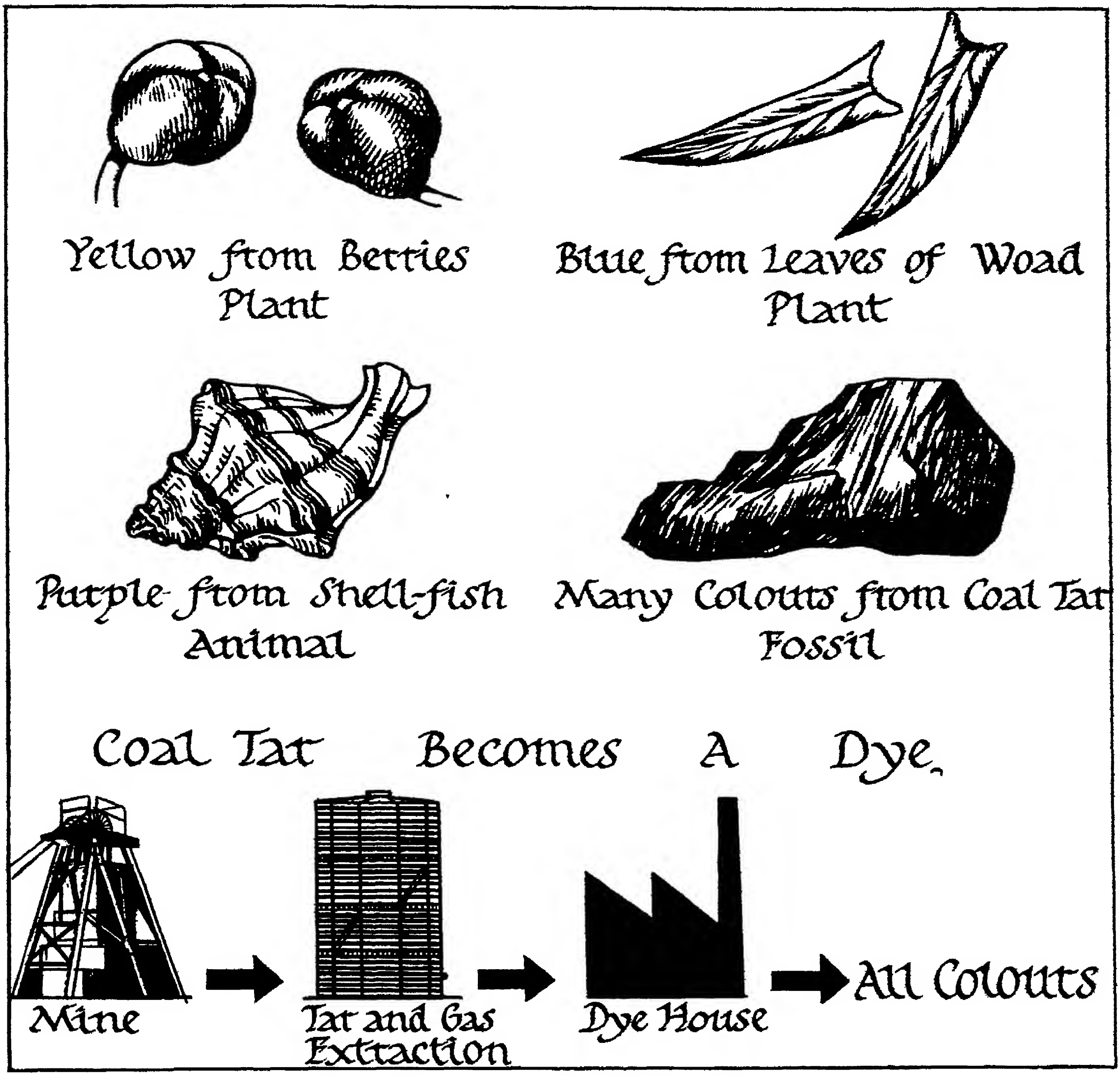
Early man used pigments for colouring, and an example of this practice was the use of woad by the Iron Age Britons. In this case the colouring matter, indigo, can be obtained in a water-soluble form, but the Britons did not know how to do this, so they used it as a pigment.

Dyeing, or using soluble colours, came later. It appears to have begun in the Far East and spread slowly westwards to Europe. The majority of the colours used came from plants and shrubs, but there are one or two dyes that had an animal origin. A scarlet dye, known in the time of Moses, came from an insect, as does cochineal. The famous dye used by the Roman Emperors, known as Tyrian Purple, came from a tiny shellfish found in the Mediterranean. About a quarter of a million of these shellfish were needed to make an ounce of the dye.

Gradually the art of dyeing became a science, but the number of dyes did not increase very rapidly. Then suddenly in the year 1856 came a very important discovery. A laboratory assistant named Perkin was experimenting with some substances that came from coal-tar and from some very unpromising material isolated a mauve dye. This single discovery led to more intensive work on the making of dyes in the laboratory instead of using natural sources. Many new colours were made in the following years. Today the search continues, for new shades, better colours, better lasting power and general improvement is still being sought.

NATURAL AND MAN-MADE

From experience you will know that colour is important in our lives. So far we have only thought of colours in terms of dyes and pigments, we have not thought about the human side at all. Just what is colour? Do all dyes and pigments look alike in different coloured lights? In the following pages we shall be exploring this subject more fully, and shall find that the colour we see depends not only on the dye or pigment used, but on other factors as well.



ALL THE COLOURS—

ALL through the long winter British gardens are almost bare of colour, but with the Spring flowers comes colour, and cheerfulness that always goes hand in hand with it. Everywhere in nature we find colour, the reds, blues and yellows of the flowers, the many greens of the leaves, the golden yellow of ripening corn, and the many colours of the rainbow. A world without colour would be a drab and depressing place, like a dull grey day in midwinter. Yet in spite of all the colour around us there are some who are not fortunate enough to enjoy it. To them the world is a place where some of the colours are missing, or, in the most unfortunate cases, where colours are seen as just shades of grey.

When we see anything we make use of our sense of sight, and for this to happen there must be some form of light falling on the object that we see. In other words we cannot see in complete darkness. But being able to see does not mean that we have a sense of colour. The colour that an object appears depends on many things. For example, it depends upon whether the person looking at the object has a complete sense of colour, upon the colour of the object itself, and upon the colour of the light falling upon it. If a green light is falling on a red flower then the flower will appear black.

We often hear commentators describe a scene as having "all colours of the rainbow". What are the colours of the rainbow? Where do they come from? Sometimes, after a shower of rain, when the air is filled with drops of water, and the light from the sun is just right, we see a rainbow. The colours are red, orange, yellow, green, blue, indigo, and violet, and we see them in that order with red on the outside of the arc. Sometimes there is a second, but somewhat fainter rainbow with the first. Is the second rainbow on the inside or the outside of the first one, and are the colours in the same order or are they reversed?

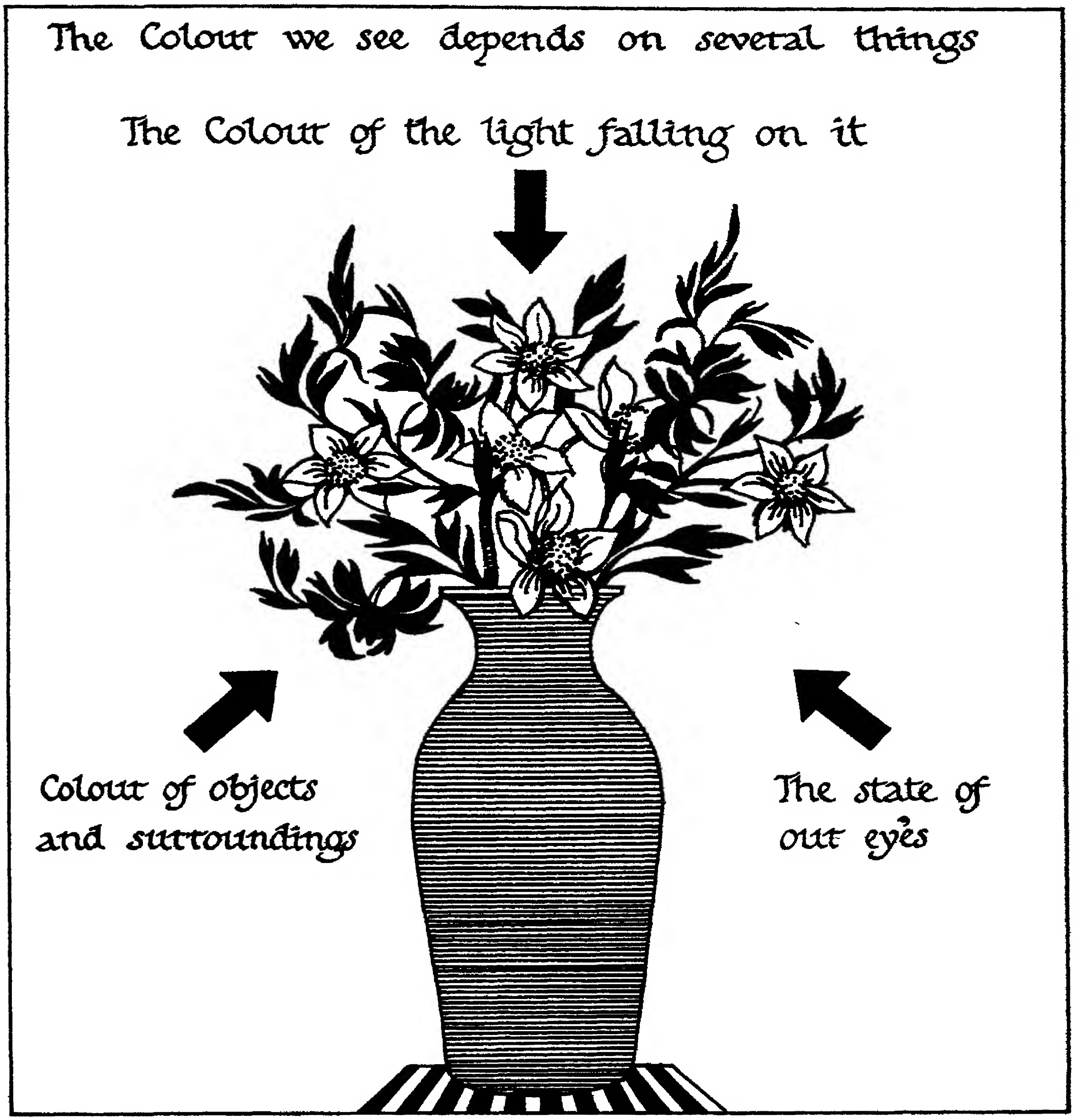
Have you ever seen a rainbow in the spray of a fountain, or in the water from a garden hose? Where is the sun in relation to you and the spray? Next time you see such a rainbow look and see.

All the colours in a rainbow come from the white light of the sun that is broken up by the droplets of water. We will imitate this breaking up ourselves later on.

Instead of breaking up white light into the various colours, we will begin with the rainbow colours and put them together. So for the

—OF THE RAINBOW

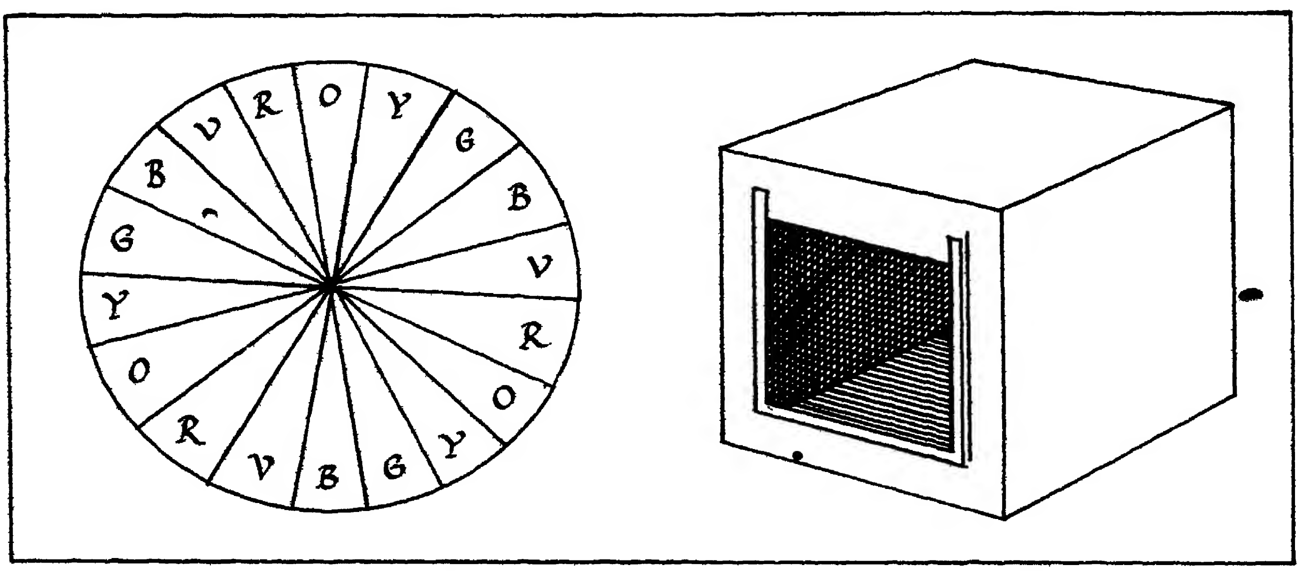
next lesson you will need some circles of white cardboard and some coloured paints or pencils, or you might like to use coloured gummed paper. The white card need only be about six inches in diameter, and you will need some pins.



RED, BLUE AND GREEN—

DIVIDE your circle of cardboard into six sectors, and then divide each sector into three as in the diagram. Colour the sectors in the following order, working round the card: red, orange, yellow, green, blue and violet. When you have finished push a pin or nail through the centre of the disc. Holding the pin flick the circle of card so that it spins round, and you will see that the colours persist for a short while and then the eye combines them and the impression is of a dirty white colour, certainly very unlike the individual colours you put on. Although this is not a true white it is white enough to show that these colours do make white. One reason that the colours do not combine to make a true white is that the colours you used are probably not pure. What happens if one of the colours is left out? Let us find out. Divide the disc into five main sectors; and then again, as last time, into threes. Colour as before, but leave out one colour; some of you can leave out red, and others blue, others green and so on. Now when you spin the discs you should get different results. Instead of white you should get different colours. If red is left out, you should see a blue-green colour. When green is the missing colour, your disc will be magenta; while when blue is missing, the result is a yellowish colour. From this you will see that, when certain colours are put together, a combining takes place; but only when you use them all do you get white.

This fact can be shown in another way. The apparatus is not so simple, but you should be able to make it. In the diagram you see how



—THE PRIMARY COLOURS

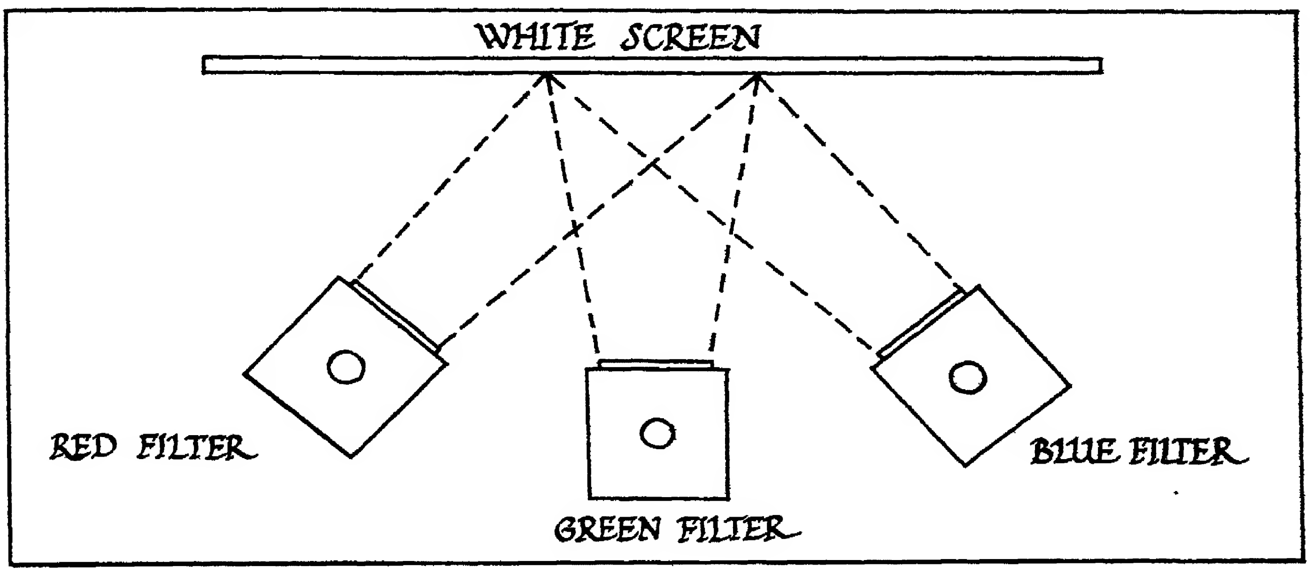
a biscuit tin can be used. A hole is cut to take a lamp-holder, and to the front wooden channelling is fixed so that coloured filters can be slipped in. If you use batteries for your lighting then you will have to use smaller boxes or tins. Polish the inside and paint the outside a dull black. You will need three of these lanterns and three filters, one red one blue, and one green. Arrange them as shown so that they light the same part of a white screen. Now in your record books copy the following table:

1st lamp	*2nd lamp*	*3rd lamp*	*Colour on screen*
Red	Green	—	
Red	Blue	—	
Blue	Green	—	
Red	Blue	Green	

By shining the lamps on to the screen in the order of the table you will get various results on the screen. Fill in the blank column for yourselves.

We make the sensations of yellow, peacock-blue and magenta by mixing the pairs of colours from red, blue and green. But we cannot make red, blue or green by mixing other colours. Red, blue and green are called the "primary colours".

The colours yellow, peacock blue, and magenta are called complementary colours. What does the word complementary mean?



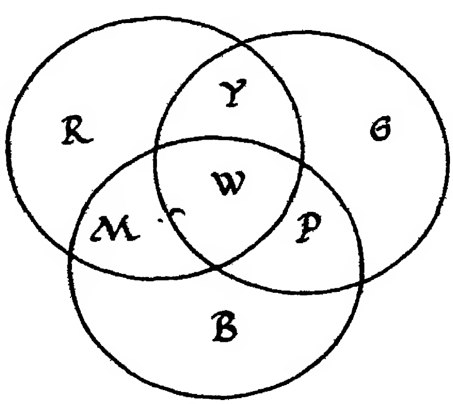
PRIMARY COLOURS AND—

THE primary colours, red, blue and green cannot be made by combining other colours, but all the other ones can. Your record books should show the following table:

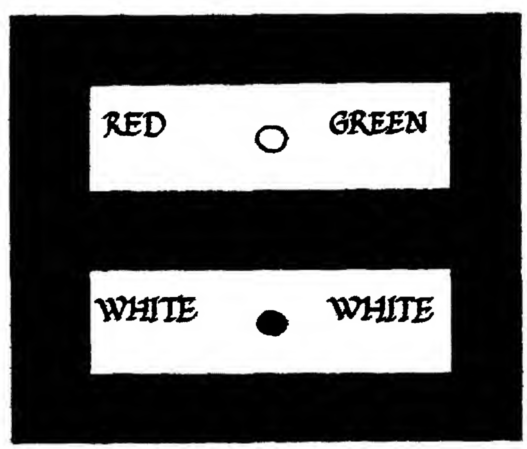
Red light	+	Green light	=	Yellow
Red light	+	Blue light	=	Magenta
Blue light	+	Green light	=	Peacock Blue
Red+Blue	+	Green light	=	White

From the above equations you can see that when magenta or yellow, or peacock blue is mixed with the primary colour that is missing from the equation then white is formed. For example if yellow is mixed with blue, the missing primary colour in the first equation, then white is formed. Try this for yourselves if you can, using your lanterns from last time. Yellow, magenta and peacock blue are called the "complementary colours", and the diagram shows how they are formed. Different shades are made by mixing the colours in differing proportions.

Now try another experiment. Paste a circle of red paper on to a piece of white paper or card. Stare hard at this red circle until the eyes tire, and then look at a sheet of white paper placed at the side. What colour do you see? Instead of seeing plain white paper, or even the



What do the letters stand for?
What does the diagram show?



Make this pattern on white paper. Stare hard at the white spot till the eyes tire. Look quickly at the black spot and watch the white areas

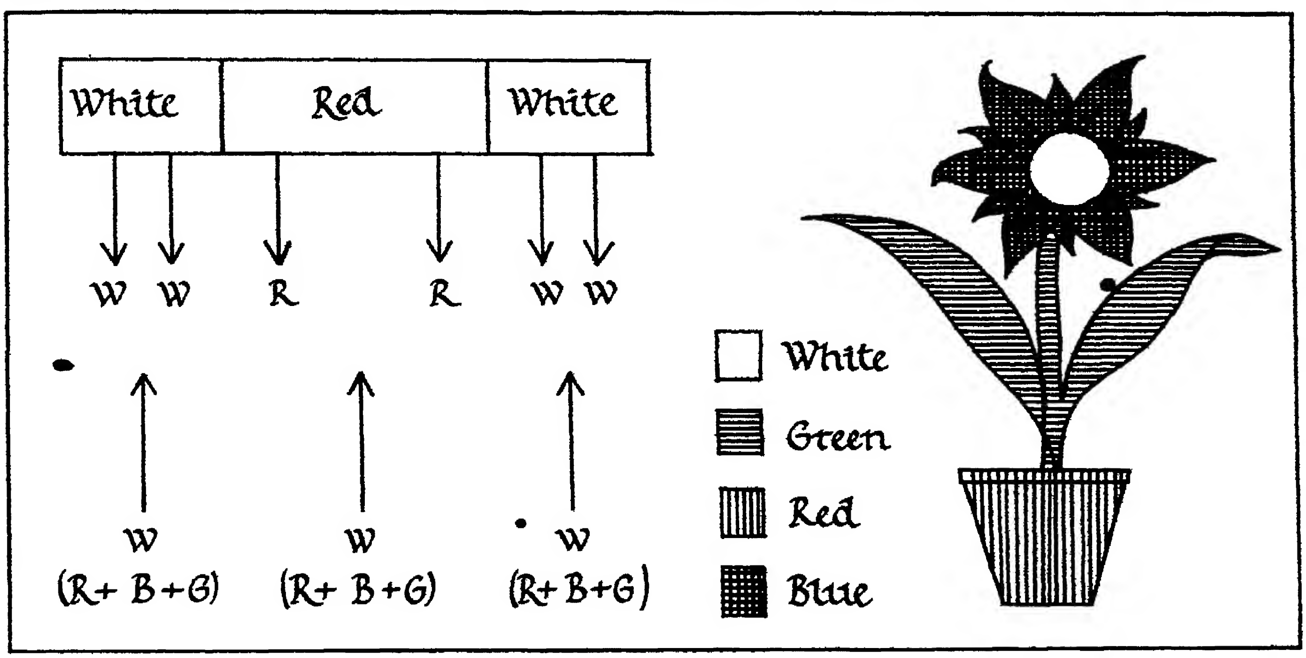
—COMPLEMENTARY COLOURS

red colour of the circle as you might expect, you should see a blue-green circle, the complementary colour. Why is this?

When white light is falling on to a white surface it is all reflected so that we see white. But after the eye has been staring at our red circle for some time the nerves of the retina of the eye which give us the sensation of red begin to tire; so when we look at the white surface which is reflecting white light (that is all the colours), the only nerve which fails to react is the one that gives us red. Therefore we see the complementary colour. Try this experiment again using in turn circles of green and blue instead.

Providing our eyes are behaving normally, the colour we see depends upon the colour of the light used and on the colour of the surface we are looking at. When white light falls on to a red surface only red light is reflected, the blue and the green light that go to make up the white light with the red are absorbed.

On a large sheet of white paper, make a coloured design like the diagram, making sure that there are big areas of primary colours and avoid, for the present, using any other colours except white. Using your lanterns light the picture first with white light, and then using your filters try using first red, then blue and then green lights. Can you explain what you see? Remember that white light is made up of red, green and blue light, and that a surface reflects its own colour.



NATURAL LIGHTING—

YOU will have seen that a picture only appears right when a white light is falling on it. When a coloured light falls upon a picture, only the parts that are lit by their own colour appear correctly, the other parts are just black. The diagram shows how the picture appears in the various lights.

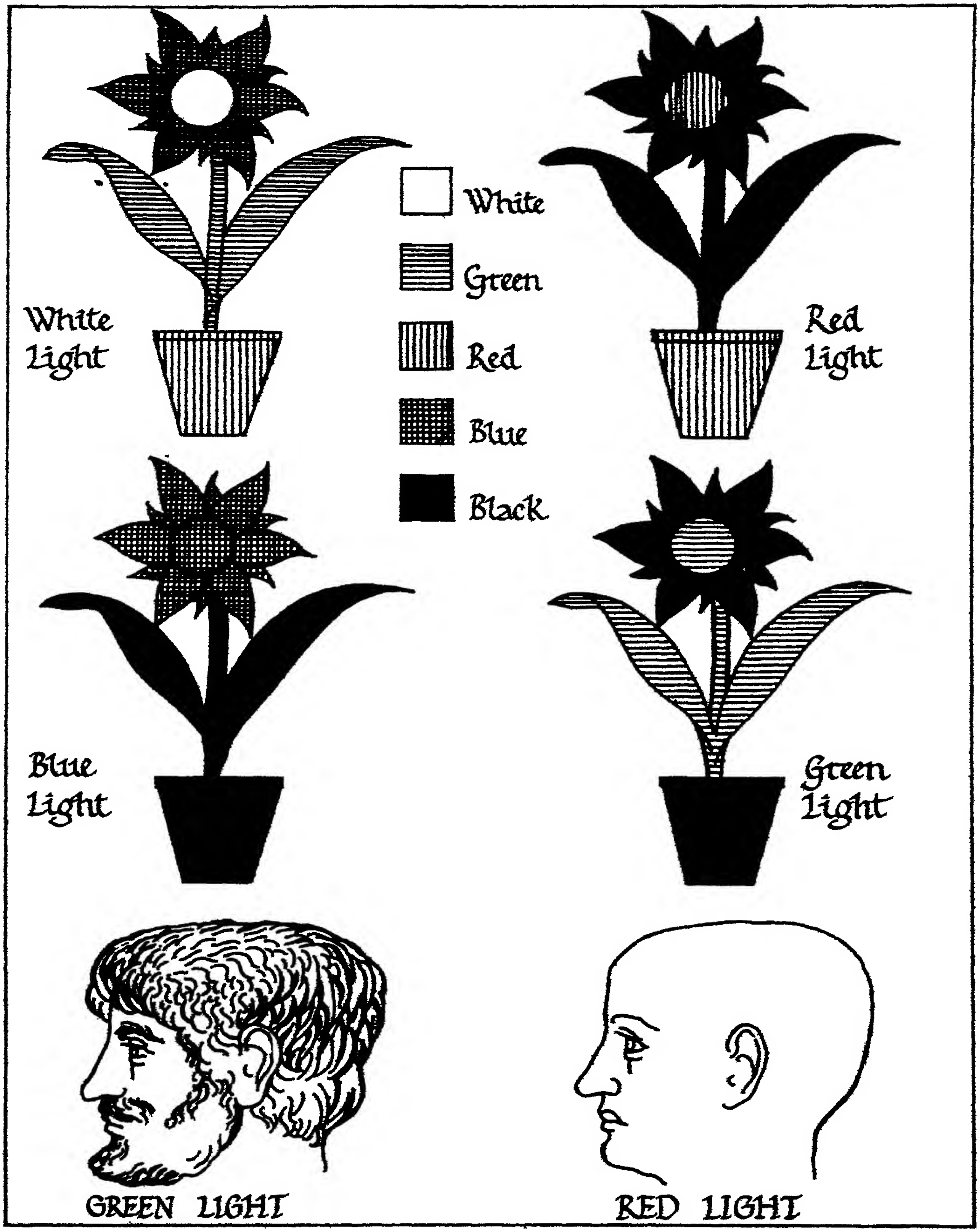
This principle is used in the theatre for stage lighting to give certain effects. You may have noticed too, that dresses and materials in shops lit artificially often look very different outside the shop in a natural light. Many shops today are fitted with special "daylight" lamps so that this difficulty is overcome.

At night you may have seen the effect that certain types of street lighting, such as mercury and sodium lamps, have. How, for instance, they give us quite an unhealthy appearance. In this case the light is not white, but is another colour with one of the primary colours either missing altogether or present in a smaller amount than in ordinary daylight.

Have you ever seen the colour of the luminous gas flame when salt is dropped into it? This type of yellow light can be used for watching the effects of a yellow light on other colours. You must be very careful if you attempt this experiment, and it should only be done if you are able to darken your classroom. Using a bunsen burner drop some salt on to the luminous flame and study various coloured pictures from magazines in this light. Make notes of how the various colours appear, and write an explanation in your record books in your own words.

We will be discussing another exhibition later on, and this year you may decide to build your exhibition around only one topic, such as "burning" or "colour". If you decide later on to do this and choose "colour" here is an amusing experiment for it, with quite a simple explanation. On a piece of white card draw a man's face in charcoal, and using a red lead pencil adorn your man's face with a beard, moustache, hair and eyebrows. Keep the drawing covered with black paper. Shine a red light on the paper, and uncover the picture. Now shine a green light on the paper. Can you explain what you see? An alternative way is to view the picture first through a red filter, then through a green filter, and with no filter at all. We shall be talking more about filters later, and you will then see if your explanation was correct.

—AND ARTIFICAL LIGHTING

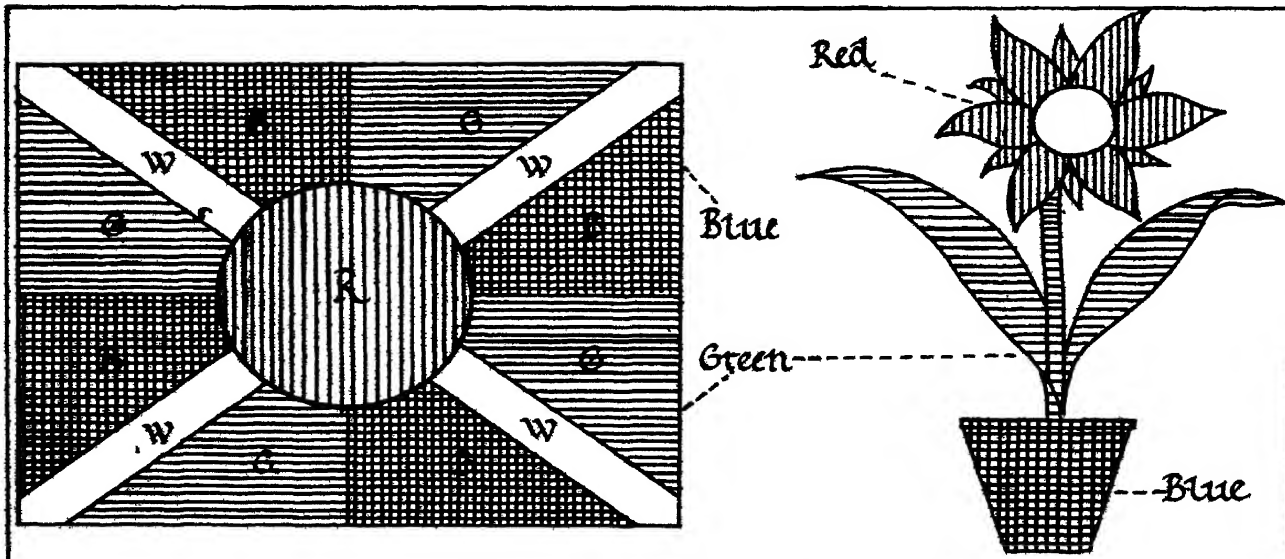


A COLOURED FLAG SEEN—

ANOTHER way of changing the appearance of things is to look at them through coloured pieces of glass or gelatine, because when you do this some colours are removed. The pieces of glass or gelatine are called filters. Of course, if you can obtain proper filters it is best; but pieces of coloured glass or some other type of material will give the same results, although they may not be quite so good.

A design can be drawn on the blackboard with coloured chalks. It must be simple, and a good subject is a coloured flag like the one shown. Or you may like to paste some shapes of coloured paper on to a sheet of white paper and hang it up. Using one of your filters at a time, look at the design in front of you. As there are quite a few variations it will be best if you keep a record in your books. The following table can be copied and completed by you as the experiment is done.

Colour of filter used	*The colour the parts of the flag appear when viewed through filters*			
	White	*Red*	*Blue*	*Green*
Red				
Blue.. ..				
Green ..				



Look at these through different Coloured Filters

—THROUGH COLOURED FILTERS

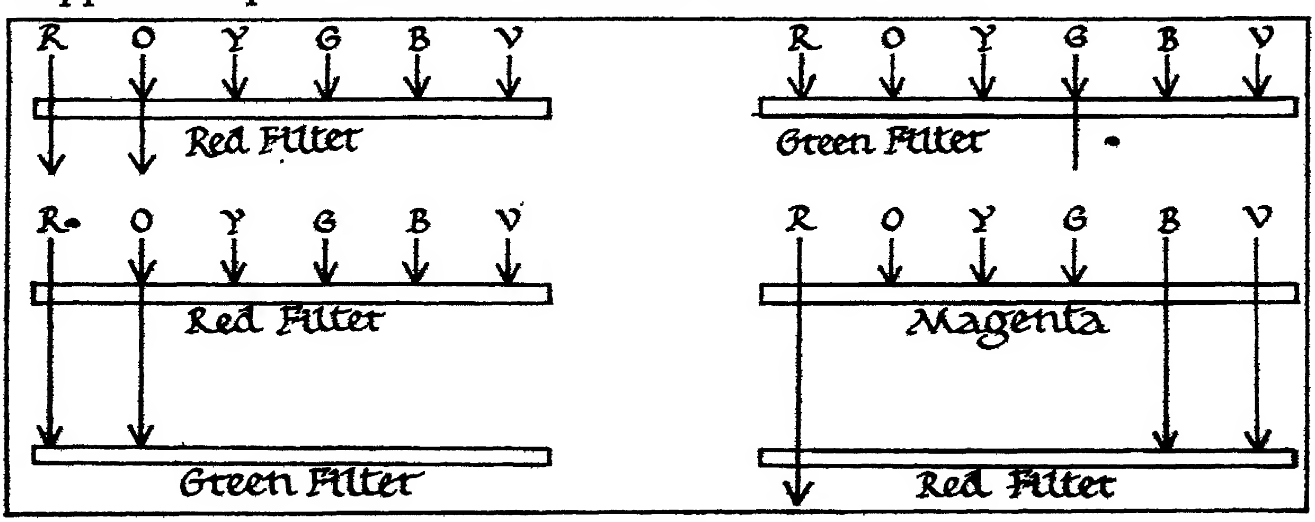
Before you begin this experiment remember that there are two important facts:

1. The primary colours, red, blue and green are pure colours.
2. The complementary colours are made up as follows:

Magenta	=	Red	+	Blue
Yellow	=	Red	+	Green
Peacock Blue	=	Green	+	Blue

Complete the table above by filling in the colour that the filters allow through. You may find that with some of the filters the results are not quite as good as you would expect, because the colours you use may not be quite the right ones, or because the filters are not quite as effective as they should be.

When you look at a piece of white paper through a red filter, although the paper reflects white light (that is, a combination of red, blue and green) the filter only allows the red to pass through. It absorbs the rest. In the same way a blue filter allows only blue light to pass through, and a green filter allows only green light to pass through. A green surface will only reflect green light; and, as this is absorbed by red filters and blue filters, the green surfaces will appear black when looked at through them. Let us look at a magenta surface through a red filter. The red filter allows red light to pass so that the surface appears red. If we use a green surface instead, then this coloured light is absorbed by the red filter, and the surface appears black. Look at the diagrams, they will help to explain what happens. What happens if a pair of different coloured filters are used?



COLOURED GLASSES—

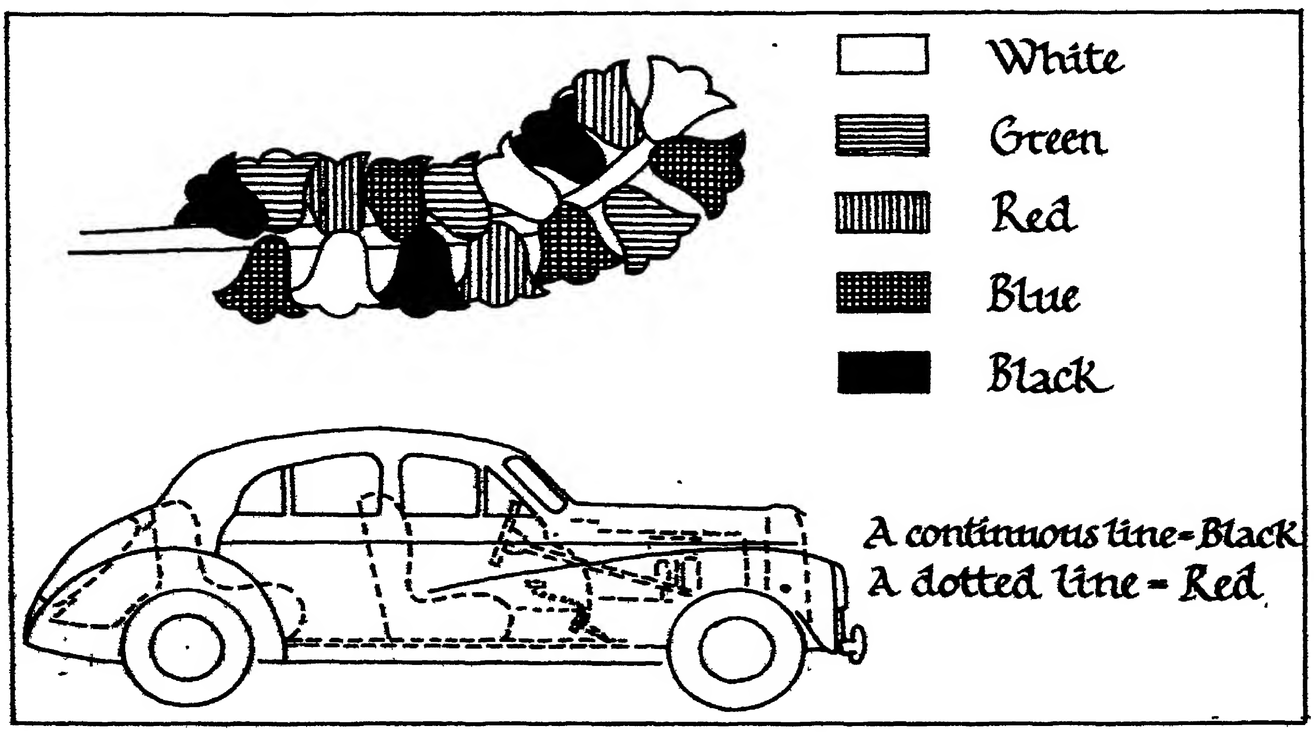
WHEN you have used your filters for several experiments you will realise that, although the red filter is perhaps very effective, the others are not quite so good. Your blue filter allows a certain amount of green light to pass through, as well as blue; while the yellow filter allows red and green through, as well as yellow.

Collect together some strands of different coloured wools and using your filters try to pick out certain colours. Unless you choose the strands of the same colour as the filters, it will be very difficult to do. Yet another way of doing this, is to make a pattern like the "hyacinth" with bells of various colours. Using your filters try to name the various colours.

Sometimes coloured filters are used in advertising. For example, the outline of a car may be drawn in black on a white background, and the interior drawn in red. When a red filter is put in a certain position only the outline is seen, but when it is moved the rest of the drawing comes into view.

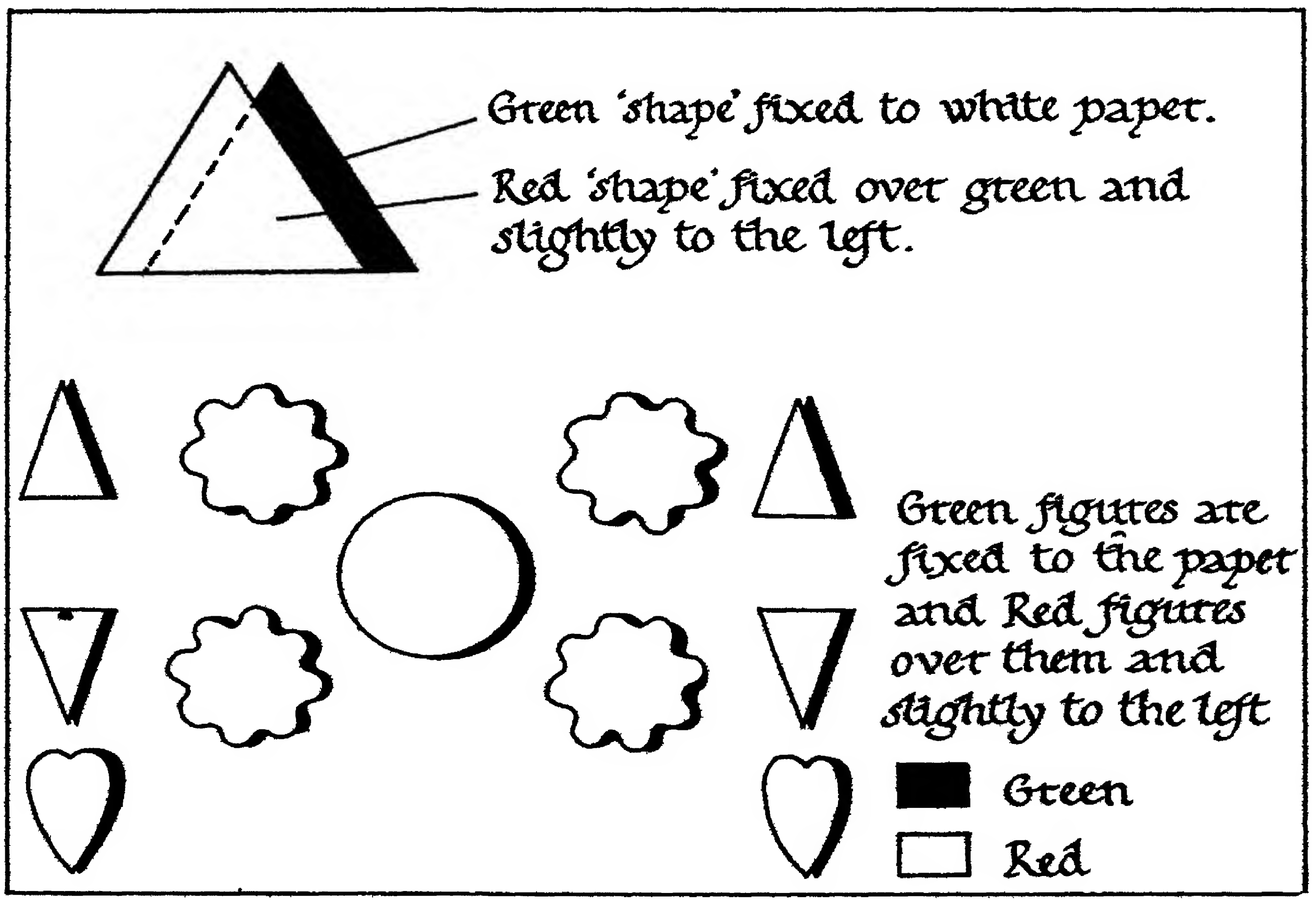
How would the drawing appear if it was illuminated by:

(*a*) a red light,
(*b*) a green light, and
(*c*) a blue light?



—TO GIVE AN EFFECT OF DEPTH

If we use coloured paper and filters we can obtain a good "stereoscopic" effect. Make a pattern or picture using red and green paper: for each shape cut pieces of the same size and shape from both red and green paper. Stick the green shape on to white paper and the red shape over it, and a little to one side so that the green sticks out a little on the right-hand side. The diagram shows you how. Build up the rest of the picture in this way. When you have completed it look at it with a red filter in front of your left eye, and a green one in front of your right eye. This arrangement of colours and filters gives an illusion of depth or stereoscopic effect. This "technique" has been used in the cinema. Pictures were taken by cameras a slight distance apart, and shown alternately in red and green on the screen. The audience looked through special glasses, one lens of which is green and the other red, and they saw the pictures stereoscopically. This technique is called "3D".



SIR ISAAC NEWTON, THE PRISM—

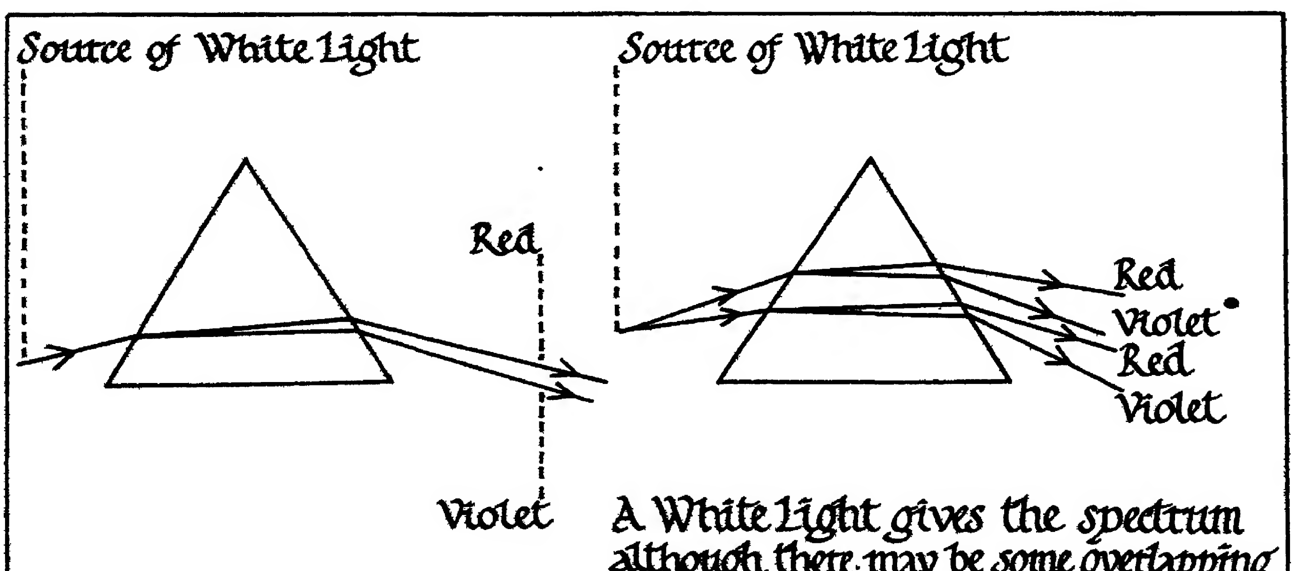
THE truth about colour was discovered by Sir Isaac Newton. He experimented with a narrow beam of sunlight which entered a darkened room through a tiny hole in the blind over the window. The ray of light fell on to a glass prism which was held so that the base was uppermost. After passing through the prism the light was allowed to fall on a white screen. Instead of a white patch of light there was a coloured band or spectrum.

When the ray of light strikes a prism, instead of it continuing on in the same straight line, it is "bent" or refracted towards the base of the prism. This bending is not the same for all the colours. Because of this difference the spectrum is formed. You can try this for yourselves. A ray of white light is adjusted so that it falls on to a prism and the spectrum is thrown on to a white screen. This can be done in daylight, but it is much more effective in the dark. When there is a point source of light, the spectrum is quite clear, but if a beam of light is used, there is an overlapping of colours to a certain extent.

In the same way that a prism will break white light up into the various colours, so a prism can cause them to re-combine. The diagram shows you how this is done. Try this and see.

An easier way of getting a spectrum is merely by looking at a white light through the prism.

When you get a satisfactory spectrum put your filters, one at a



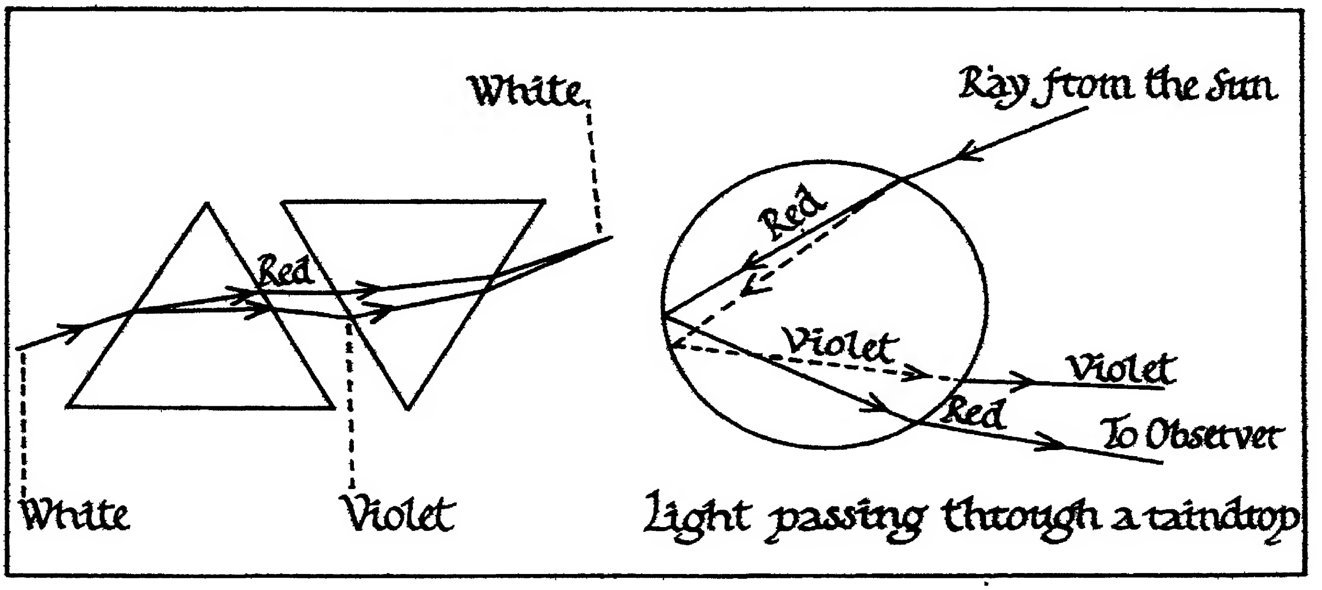
—AND THE RAINBOW

time, between the source of light and the prism. Can you explain what you see? Are your filters perfect? Do the results agree with what you have seen before?

A rainbow is a natural spectrum. The path of light from the sun is changed by the droplets of rain and at the same time the drops act as a prism, so that when the light emerges from the raindrop it has been separated into its various colours. You will see that the observer must have his back to the sun to see a rainbow. When a second bow is seen within the other the path of light through the raindrops is not quite so simple and instead of red being on the outer edge of the bow as in the first bow, it is now the inner edge of the second bow.

An important application of our knowledge of the behaviour of coloured lights is in the use of "fog lamps". In a fog, if an ordinary headlamp which gives a white light is used, the blue light is reflected back by the small particles of moisture of fog making it very difficult for the driver to see. But light from a yellow fog lamp contains no blue light, only red and yellow, and so there is less reflection and far less glare.

Find out why the rising and setting sun often appears red. When a white light is focused by a converging lens such as a magnifying glass, the edges of the spot formed are often coloured. Can you suggest why?



Light passing through a raindrop

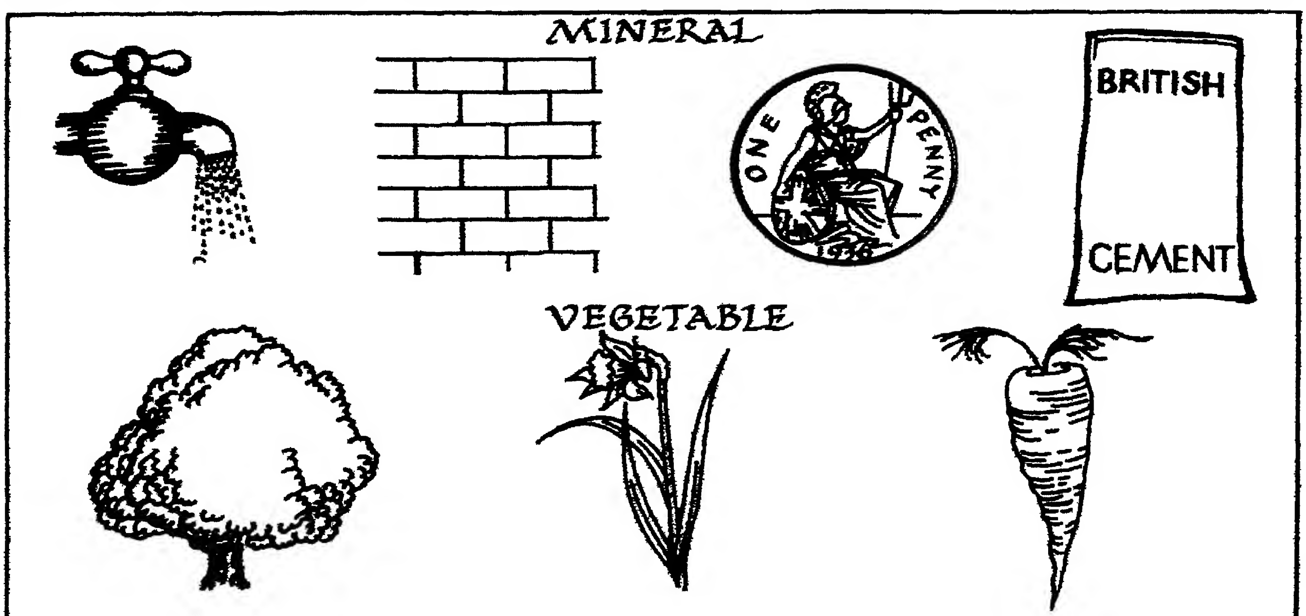
ANIMAL, VEGETABLE—

MANY of you will have heard of the phrase "Animal, Vegetable and Mineral", but how many of you know what it means? Did you know that everything on and in the earth can be listed under these three headings? What is the difference between them?

You all know what animals and vegetables are, and under these two headings can be listed all things that live. But minerals are quite different and comprise all things that have no life at all, such things as rock and stone come into this group.

What is the difference between animal and vegetable? All things that are animal can move about, but all things that are vegetable cannot. But they are alike in other respects, that they all breathe and need food. Both grow and are capable of repairing damage to themselves, if it is not too bad. Why do animals move about, yet plants do not? Plants stay in one place and take their food from their surroundings; and their supply is rarely used up, since a large amount of it either comes from the air, or from decaying matter in the soil, which is plant life returned to the soil. Animals, on the other hand, must move about in search of their food, moving from place to place as the supply is used up.

But the difference between animals and plants is not quite as simple as it appears. When you have been to the seaside have you ever seen sea anemones? Although they may look like flowers, they are



—AND MINERAL

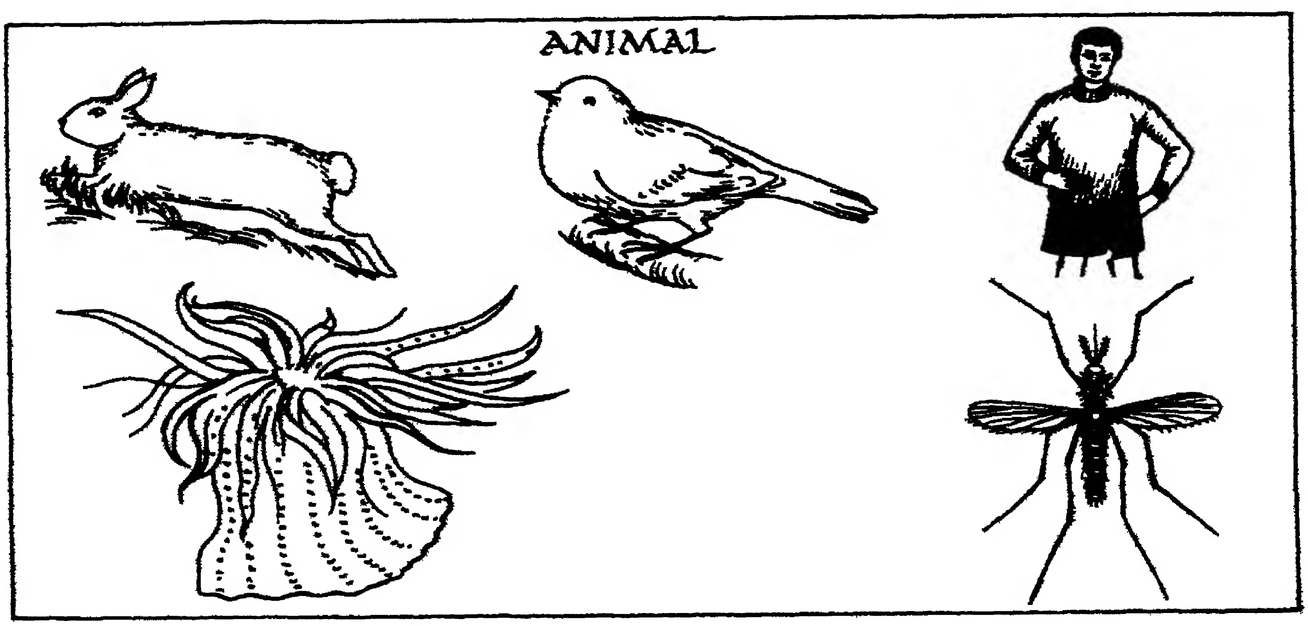
actually animals. They spend all their life fastened to one place on a rock, but they can move just a little. The tentacles of the anemone help it to catch its food, very often the tiny fish to be found in rock pools.

Then there is a plant called the "sundew" that grows in some parts of Britain, and which has tentacles with a sticky fluid on its leaves. This plant catches flies and other insects with the tentacles and "drowns" them in the drop of sticky fluid in the centre of the leaf, and then digests the soft parts of the insects. The sundew and the sea anemone are very similar; why is one a plant, and the other an animal?

Animals take in food that is either alive or that has been alive very recently, whereas the plants use non-living matter for food, such as minerals from the soil or gases from the air. The sundew plant makes use only of the materials from the decomposing fly or insect for food. Animals, too, generally have a mouth and some means of digesting their food, while the plants very often take in food all over their bodies.

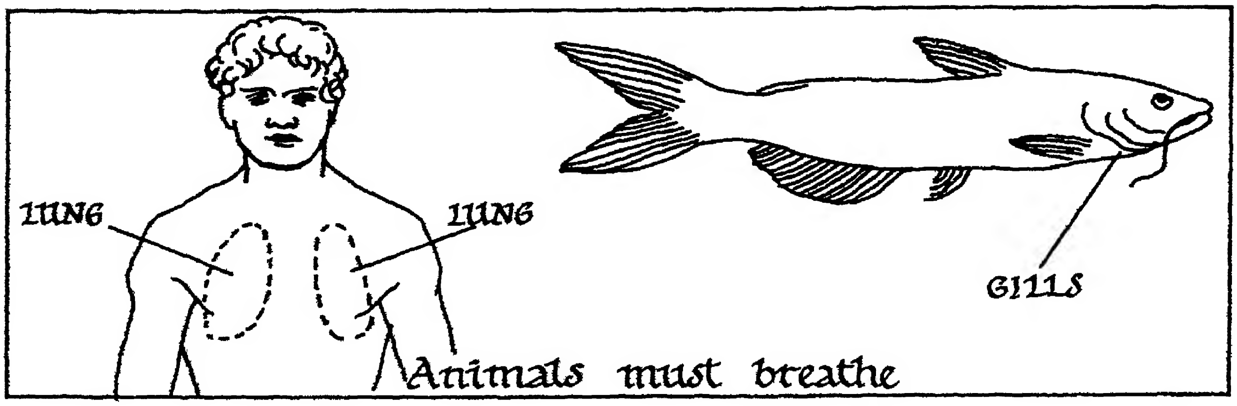
Here are some questions for you, try to find the answers:

1. Crystals "grow", are they alive?
2. Where do our bath sponges come from? Are they animals or plants?
3. How do the following get their food: oysters, worms, mistletoe, mosquitoes?

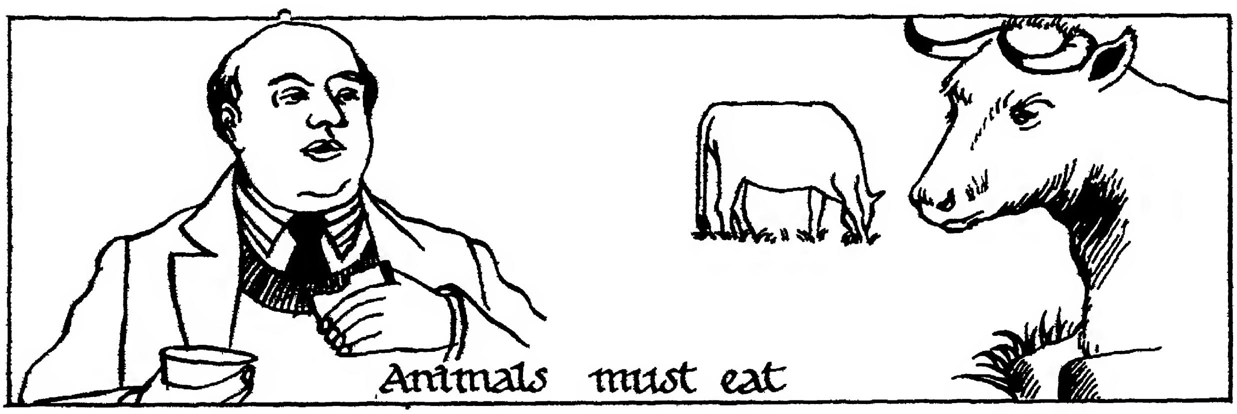


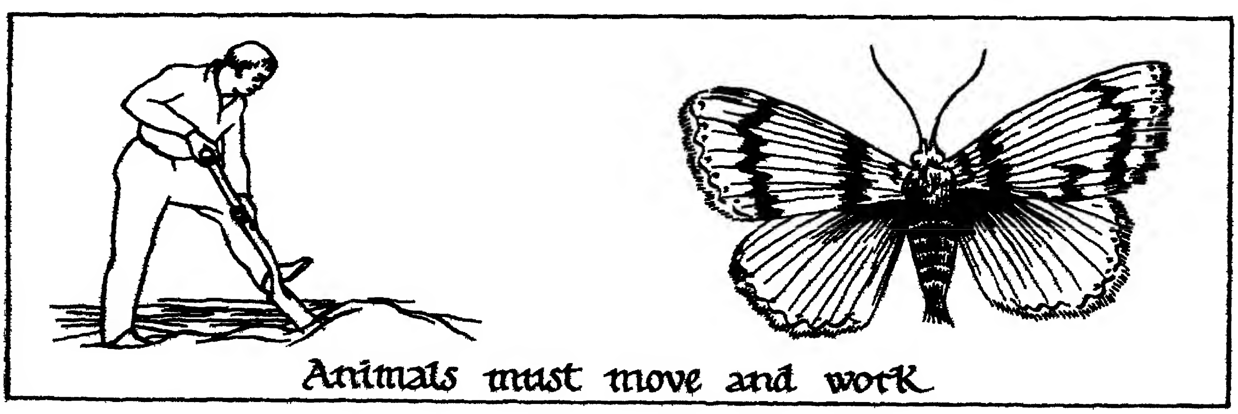
ALL ANIMALS HAVE—

ALL animals, and man is an animal too, have the same simple needs if they are to stay alive and to grow. If these needs are not satisfied then the animal will die. In some cases if the need is extremely important the animal will die quickly, in others the death will be lingering.



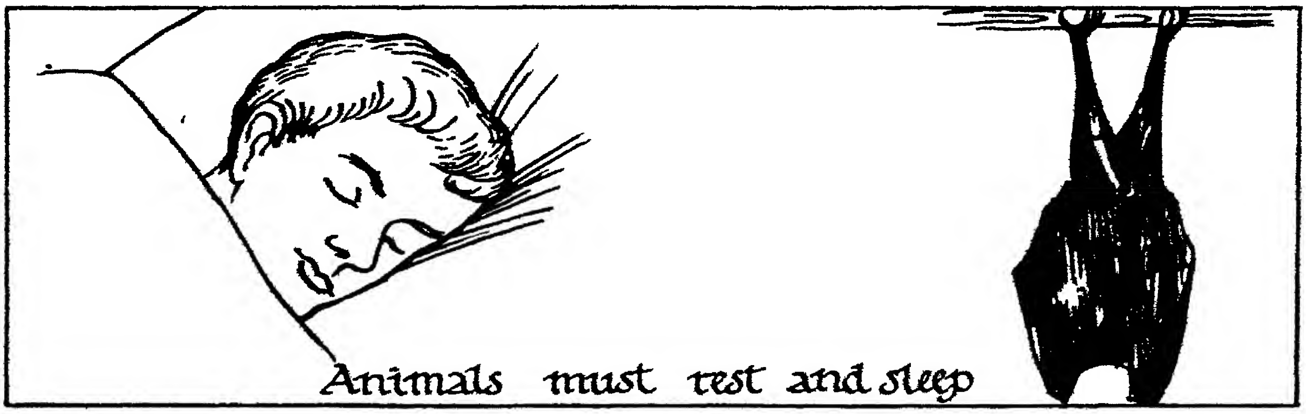
Animals must breathe


Animals must eat

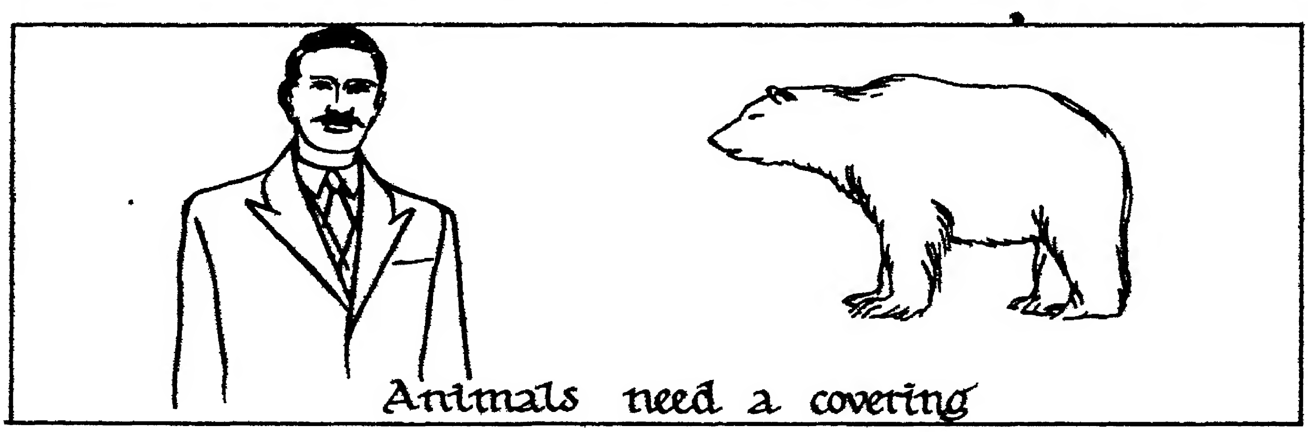

Animals must move and work

—THE SAME NEEDS

These needs are few in number, and some of them are obvious, and usually taken for granted. Not all animals satisfy their needs in the same way, indeed the ways can vary greatly. In each of the following drawings you can see how a need is satisfied by man and by another animal. Can you think of similar examples?



Animals must rest and sleep



Animals need a covering

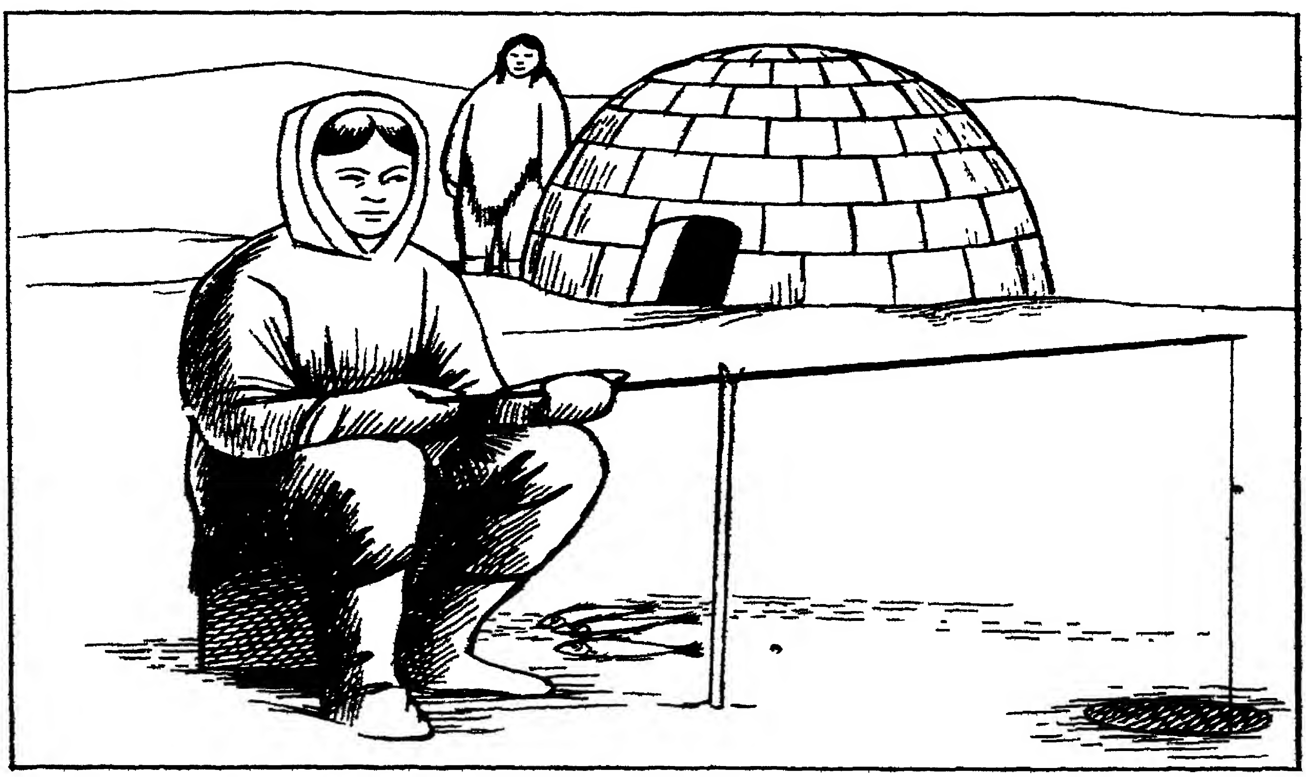
Animals need shelter and protection

PRIMITIVE MAN—

THERE are certain essential needs that must be satisfied if man is to remain alive and to flourish. These essentials include the need to breathe, move, sleep, eat and produce children. Most of these essential needs do not vary among the races of man but the way in which man obtains his food does differ from race to race and also from one part of the world to another.

The improvements in man's way of life have resulted from his contact with other races and the use of any natural resources which may be available to him. Thus the people we call civilised are often those who are in contact with other races and who have rich natural resources, and have gained the knowledge and ability to use them through this contact. On the other hand primitive people are often those who live out of contact with other races, without rich natural resources, or, if they have them, without the knowledge and ability to use them.

With modern conditions of travel and communication civilised peoples often supplement their own resources with the products of other countries. Thus, in Britain, where we no longer produce enough meat for our requirements, we import it in large quantities rather than

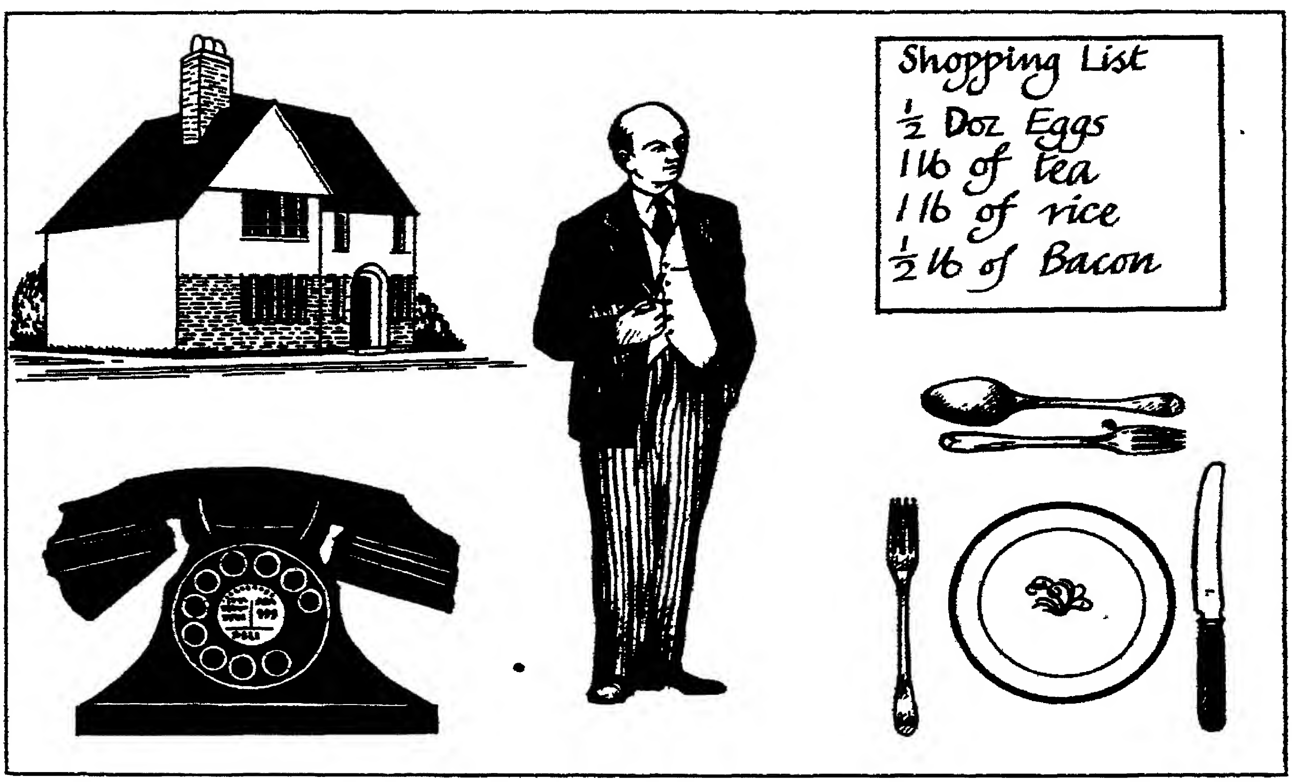


—AND CIVILISED MAN

reduce the amount that would be available to each of us if we relied upon home-grown meat. On the other hand Eskimos, with limited access to the outside world, must satisfy their need for food from their own resources. The importation of certain foods may lead to a greater number of ways of satisfying the basic need; for example, imported wheat may supplement or replace home grown rye or rice. Not all the civilised peoples have to import food, and America, Russia and Australia produce all their own requirements. This is not so with all the races of the world.

Today man still has to protect himself from the animal world. With primitive peoples this protection is often against the larger animals, while with the more civilised the important enemies are generally the smaller animals such as insects. All peoples of the world must guard against bacteria which are really plants.

In the pictures here you can see the difference between the way of life of a civilised people and that of a primitive people. What is the meaning of civilised? Why are primitive people not necessarily uncivilised?



GETTING TO KNOW—

THE human body is a most complicated machine which is capable of the heaviest of work as well as the most delicate of movements. Let us look at some of the chief parts and see how they fit into the whole.

Look at the diagram. Here you will see the main features of the human body. Not every part is there; only the biggest ones are shown, so you must remember that many smaller parts, although vital to the efficient working of your body, have been left out. These we will be talking about later on.

The body is reinforced by a framework of bone. This framework must be strong and firm, yet not rigid, otherwise we would not be able to bend and move about. Therefore certain parts of this framework are made up of smaller bones and joints that allow movement. Other bones protect vital organs of the body. Can you see any parts that are protected in this way? The bony framework of the body is called the skeleton.

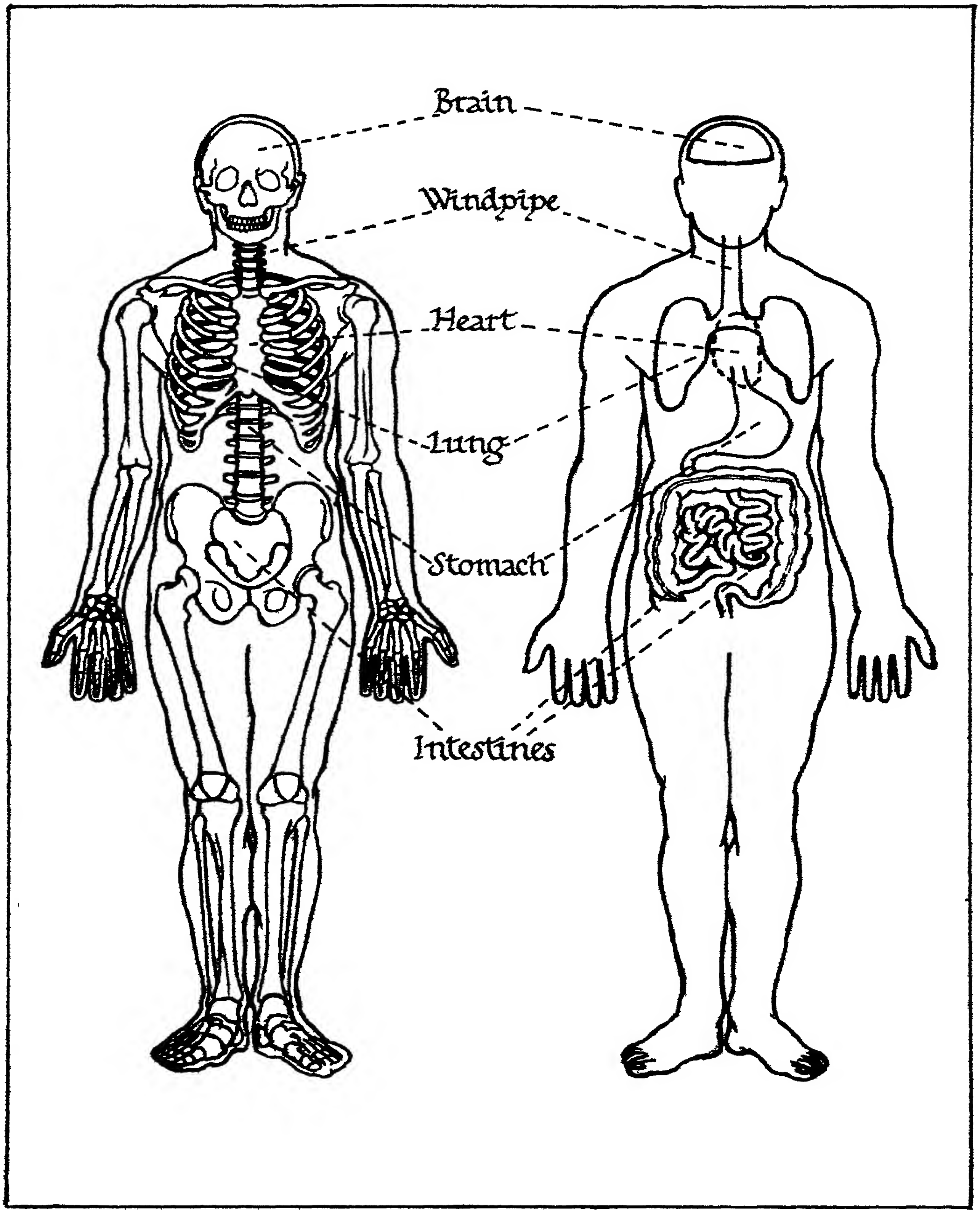
Over all this bony framework there are muscles which control the movements of the various parts of the body.

Our skin, which we have talked about earlier in this course, forms a watertight protective layer that keeps out dangerous bacteria. In order that all parts of the body can function properly a supply of blood must go to them and from them. The heart acts as a pump sending out the blood through the arteries until it reaches the farthest points of the body, from whence it returns through the veins. By this means the blood is constantly circulating round the body.

Another necessity is an air supply. We all have a windpipe to enable the air to get to our lungs from our mouths and noses, and to enable the used air to pass out again.

To keep our bodies moving, energy is needed and this comes from the food we eat. Our bodies are equipped to deal with this too. The mouth, containing the tongue and teeth, passes the food through to the stomach and then to several yards of "tubing" at the end of which the food has been sorted into the material that is necessary to the body and that which is just waste and has to be discarded. As well as solid waste there is also liquid waste which is formed as the body uses the food that it wants. The brain, through the nerves and the senses, is the means of control of this complicated body. We shall discuss this later.

—ABOUT YOUR BODY

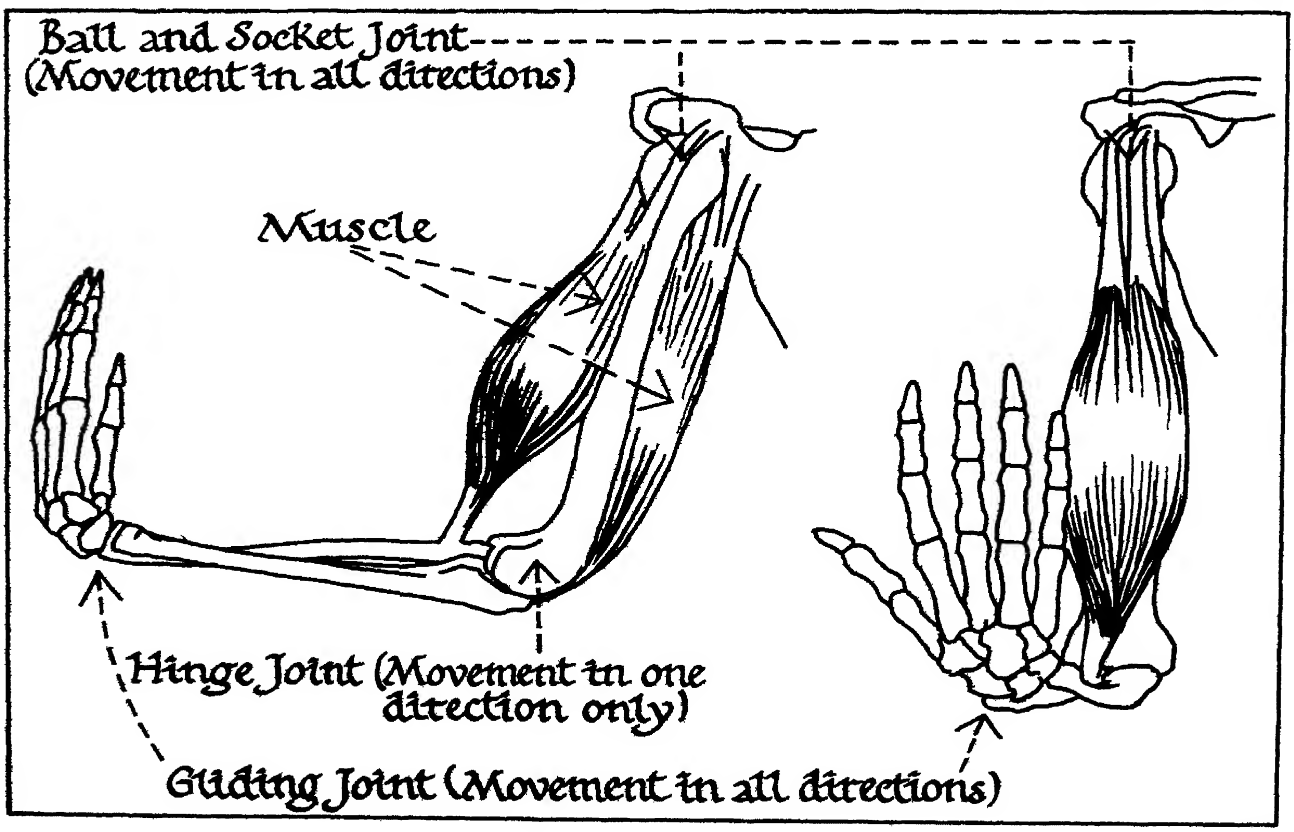


THE JOINTS IN—

THE skeleton is important to the body, both for protection and support. For the body to move about, something else is needed; muscles. Movement is caused by certain muscles shortening and lengthening. So that this can happen, the bones to which the muscles are attached must be able to move, and movement of parts that are fixed to each other requires joints.

In our bodies are several types of joint, each fulfilling a different function. Here are examples of three of them. When movement takes place in one direction only, there is a hinge joint as in the knee. Some of our bones can move in any direction and for this type of movement there must be another joint. Thus in the shoulder we have the ball and socket joint. Where is there another ball and socket joint? The joints in the wrist and ankle are made up of many bones because quite a lot of sliding movement must take place here. They are called gliding joints.

Because a muscle can generally only pull and cannot push, most muscles are arranged in pairs, as in the diagram of the upper arm.

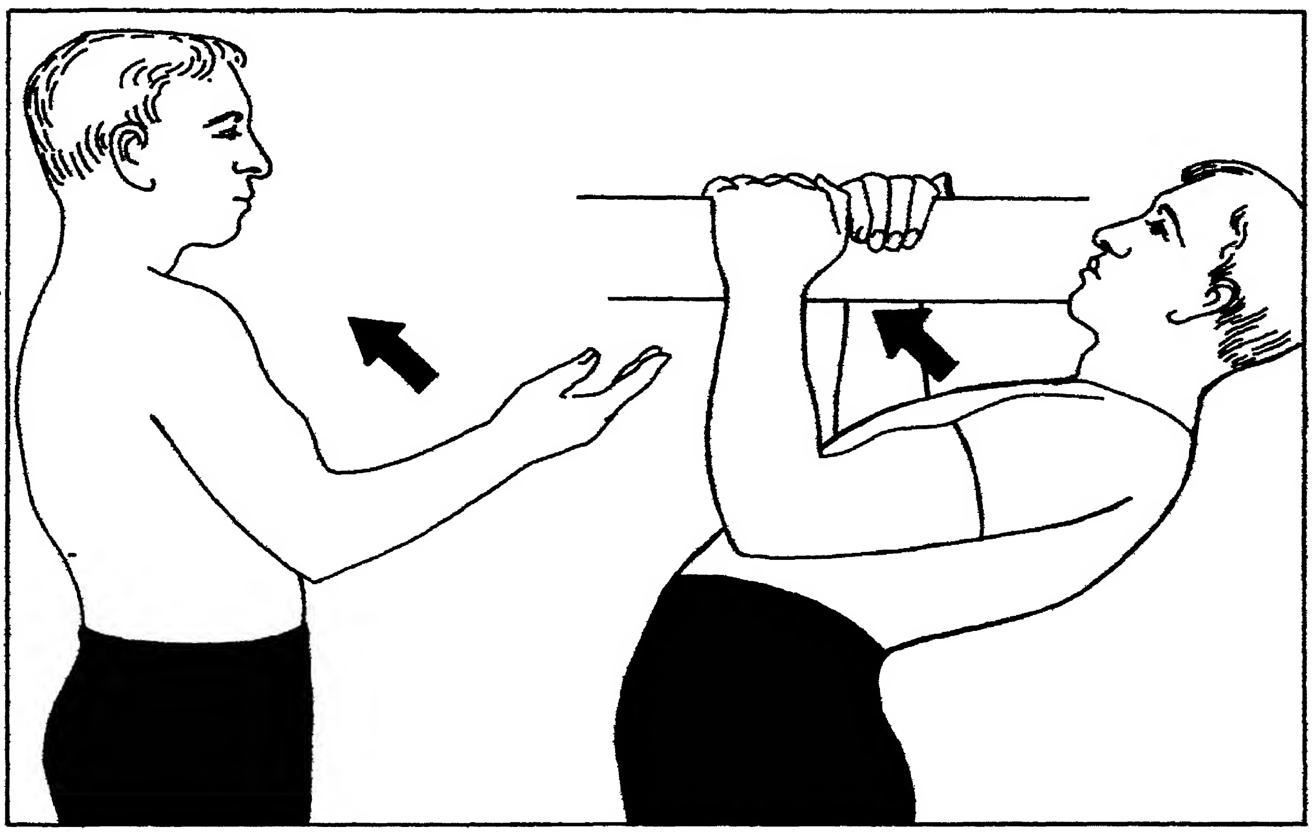


—YOUR BONE STRUCTURE

When a muscle is doing no work, it is long and thin, but when it is working it is short and fat. When a muscle contracts it is not the same bone that moves every time. As you can see in the diagrams, when the muscles of the arm are shortened, either you can bring your hands up to your shoulders, or pull your shoulders up to your hands. These muscles are attached to the bones by very strong tendons or cords.

Although our joints are constantly in use during the day, why is it that they give us such little trouble? Neighbouring bones are held together by ligaments which make the joints firm and the whole joint is often enclosed in a kind of bag which is lined with a tissue which makes a "lubricant" for the joint so that it works smoothly. Again, to help smooth movement the ends of the bones are covered by a kind of gristle which is called cartilage.

As you study your bodies you will probably come across words that may be quite new to you. They will be the names of parts of your body and functions of your body and will be something more to add to your store of knowledge.



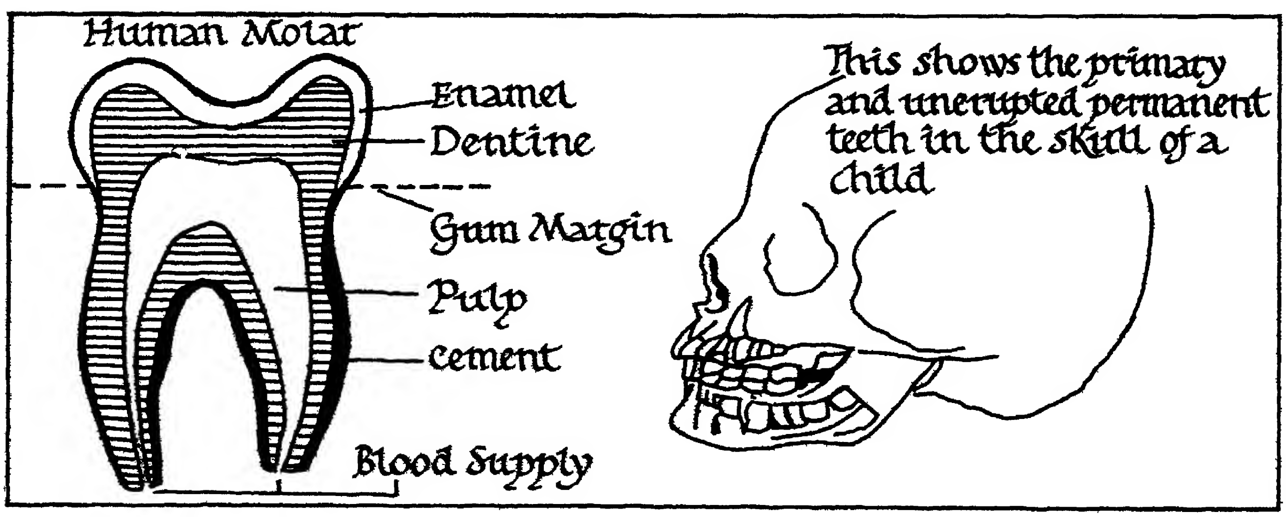
YOUR TEETH ARE PART—

AS you grow so do your bones. A newly born baby's bones are soft and will bend and curve. This sometimes happens when babies are allowed to put the weight of their bodies on to legs which are not strong enough. The legs become bandy or bowed. Bones go on growing until we are about twenty-five years old, but our bones do not bend. Did you know that bones only grow in certain places? A bone may perhaps be made in two or three pieces, and growing only takes place between the pieces. Because of this, there are several hard pieces joined by soft parts so that the chances of bending are lessened.

A baby's bones are made of gristle or cartilage, consequently they are not so rigid. That is why when a baby has a nasty fall the bones bend; whereas an adult, whose bones are more rigid and brittle, would suffer a true fracture. Have you ever heard of a greenstick fracture? All the while the bones are growing, "cells" are replacing the cartilage with a much harder material which is mainly calcium phosphate. In this way the cells are working, slowly building the bones longer and thicker. This hard mineral comes from some of our food, for example milk and cheese.

Marrow runs through the middle of many of our bones. It is made of fat and blood cells. In the marrow blood cells are made, and when they have finished growing they pass out of the marrow into the blood which is supplied to the marrow and into the main stream to begin their work as carriers of oxygen.

The teeth are an important part of our bone structure. The new



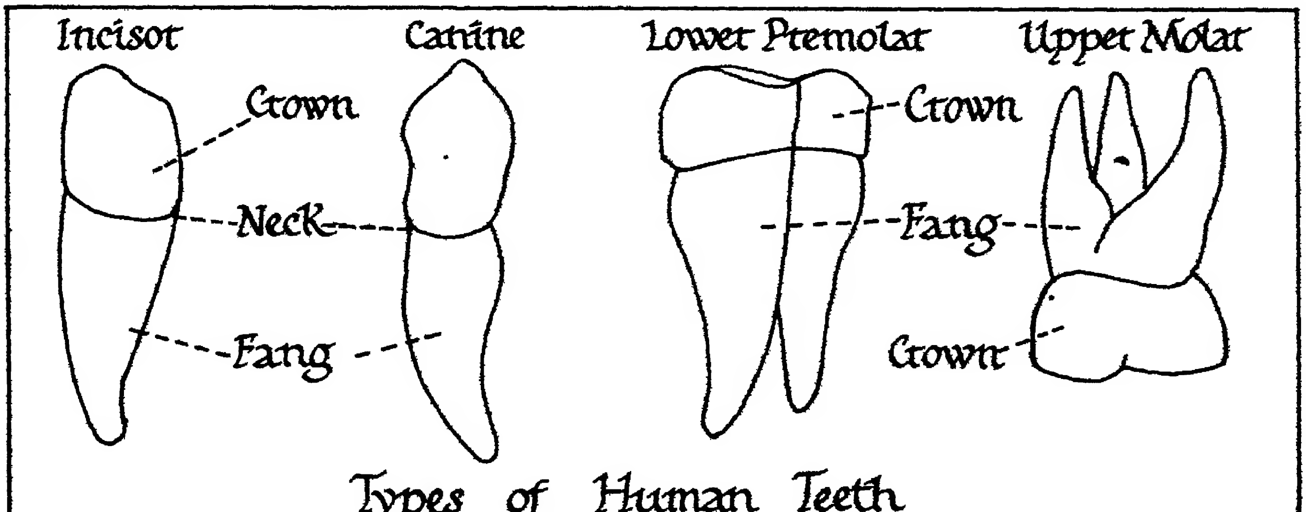
—OF YOUR BONE STRUCTURE

baby has teeth hidden away in its gums when it is born. When it reaches the age of about six months the teeth begin to appear. They go on appearing, we call it erupting, until at about two years the baby should have all twenty of its first set of teeth. These primary teeth are very important, for they not only allow the child to eat more solid foods, but they help the jaw to expand normally so that when the permanent teeth are ready to erupt there is room for them. It is necessary, therefore, that the first teeth should be preserved until this time.

The first of the permanent teeth begin to erupt at the back of the gums behind the primary teeth when the child is about six. At the age of thirteen most of the permanent teeth should have erupted, taking the place of the primary teeth which are often shed naturally. The last teeth to erupt are the wisdoms, and they make up the full adult set of thirty-two, which have to serve us for the rest of our lives. There is no third set waiting to erupt; so take care of your teeth.

Teeth are divided into incisors for biting, canines for tearing, and pre-molars and molars for grinding, but they are all made in the same way. Look at the diagrams. A tooth consists of a crown, neck, and root. The root is covered with "cement", the crown with enamel, and in the centre of the tooth is the pulp, made up mostly of nerves and blood cells, and surrounded by the hard "dentine".

Why are canine teeth so called?



Types of Human Teeth

FOOD AND OXYGEN—

IT is easy to see the purpose of many parts of our bodies. But some are more obscure, for example the purpose of the blood. Our blood has several duties; one is to carry fresh air to the cells of the body and take away used air; another is to carry food to the cells that need it.

To get to all parts of the body, the blood has to be pushed, or pumped. Our hearts are the pumps. Blood does not flow in a steady stream but in jerks. Why is this? Where is your heart? Put your hand over your heart and feel it beating. Your heart has four compartments, two above and two below. The two above receive blood in, the lower two force it out again.

In its journey round the body the blood passes twice through the heart. The first time the heart sends it to the lungs where the blood exchanges the used air that it is carrying for fresh air that is breathed into the lungs. Carrying the fresh air it goes back to the heart where it is re-directed into the arteries and through these to all parts of the body, supplying fresh air and taking in used air in place of it as it goes. The arteries divide and sub-divide until they become tiny tubes called capillaries. By the time the blood has passed through all the tiny capillaries it has given up all its fresh air and food to the cells of the body. Then it returns to the heart through the veins. Like the arteries, the veins on the return journey are small in the farthest parts of the body, gradually linking up and getting bigger until at the end of the journey, at the heart, the veins are as big as the arteries, by which the blood left the heart.

In the veins there are valves and they stop the blood running backwards. They are so arranged that the blood moves always towards the heart, and so prevents it going the wrong way.

Why are there no valves in the arteries?

Why cannot you feel a pulse in the veins?

When you cut your hand, the bleeding is only slight, unless of course the cut is very deep. The blood is lost because the capillaries near the surface of your body are cut, but clotting of the blood soon occurs and the bleeding stops. However, a deep cut may sever an artery and the blood will spurt out, or if a vein is cut the blood will flow out steadily. Why is there this difference?

Later on we shall see how to give first-aid treatment for cuts and minor wounds.

—ARE CARRIED BY THE BLOOD

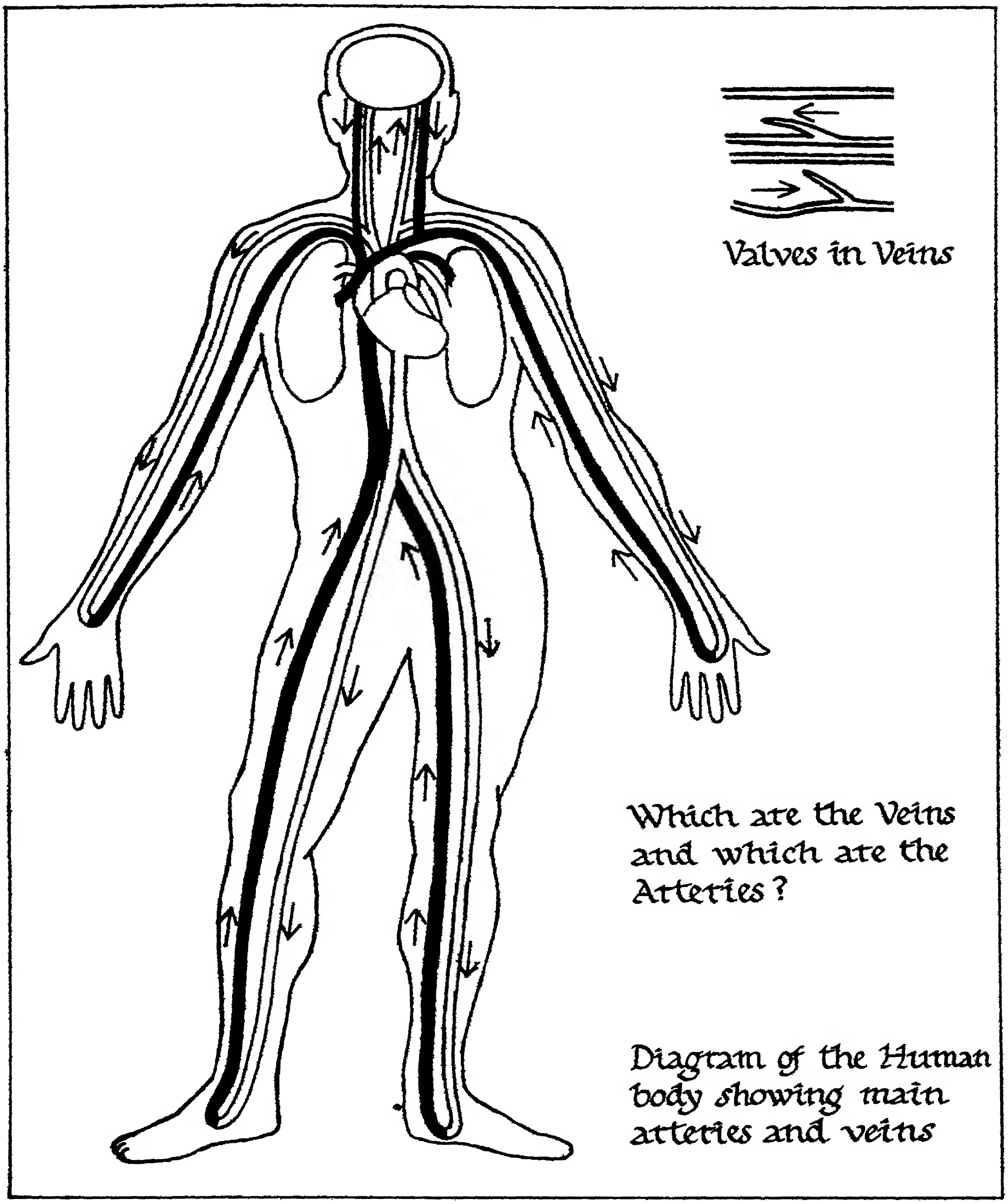


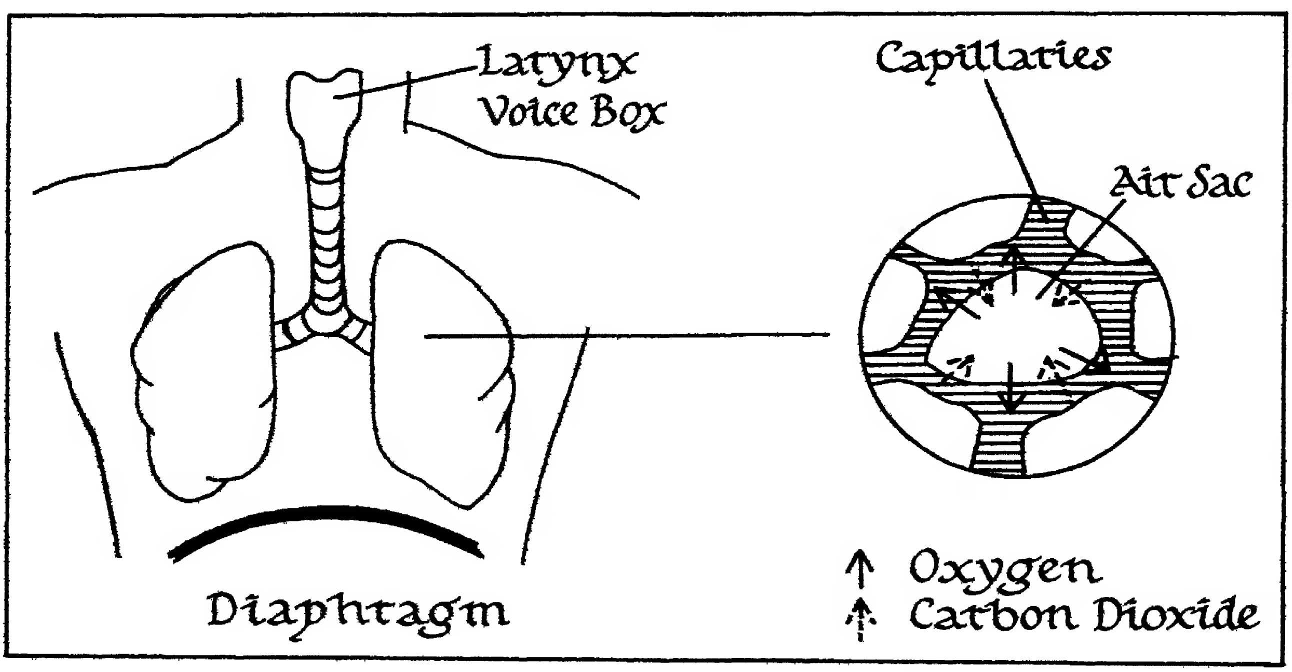
Diagram of the Human body showing main arteries and veins

BREATHE THROUGH THE NOSE—

WE all breathe so that we can remain alive, and we do it quite unconsciously. But there are occasions when our need for air is painfully obvious such as when we try to "hold our breath" for too long, or when we are "winded" after a race. To breathe is an essential of life, and to remain healthy everybody must have a plentiful supply of fresh air. Just as we need to take in oxygen in the air, so we have to get rid of the waste carbon dioxide that is collected in the blood.

To understand how your lungs work imagine that your chest is a pair of bellows. When the sides of the bellows are held apart the space inside is increased and because of the air pressure outside air rushes in. When the sides are squeezed together again the air is forced out. In the same way air passes in and out of your lungs, except that it is done without conscious effort on your part.

The ribs form a cage over your lungs, and the space within is made bigger when the ribs are lifted upwards and outwards by the muscles which cover them. At the same time the breast-bone is also lifted a little and a large arch of muscle flattens downwards. This arch is called the diaphragm. When this happens air is drawn down the wind-pipe into the lungs. When you breathe out again the opposite happens. The space inside your chest is made smaller and air is forced out again.



—NOT THROUGH THE MOUTH

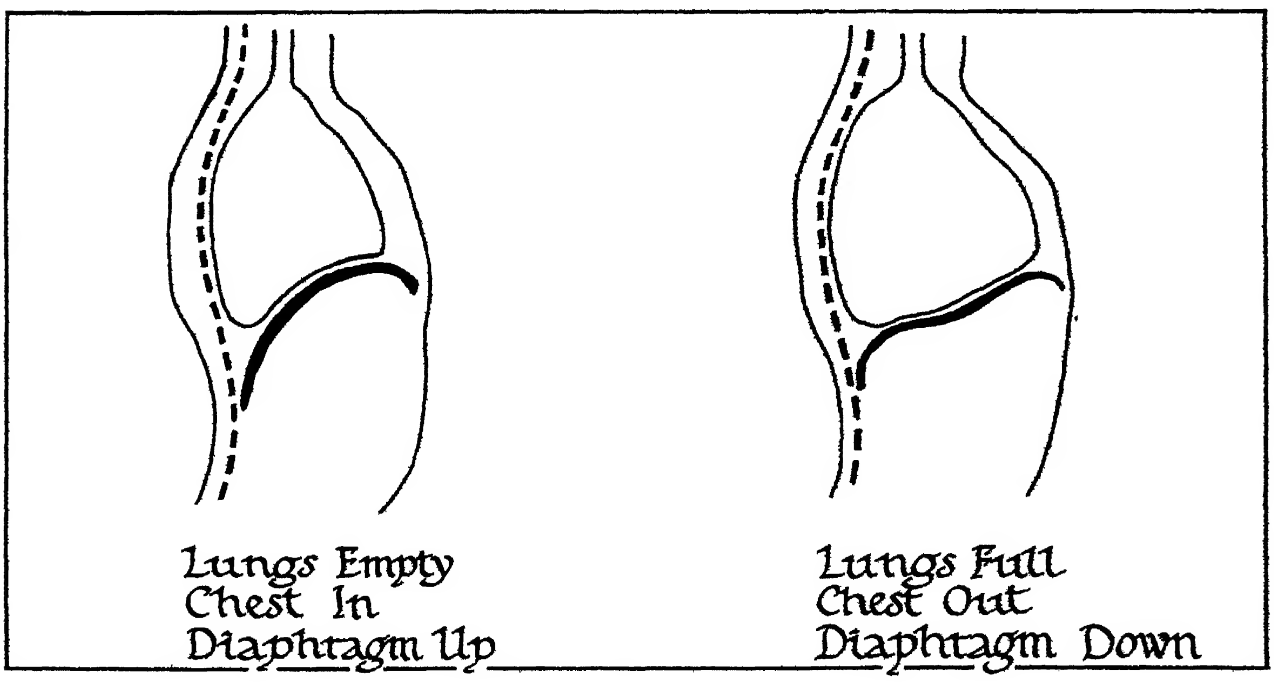
Air enters the body through the nose and mouth. When it passes through the nose air is warmed and is filtered by the tiny hairs that grow in your nose, and by the moisture that is always present there. You may have noticed when blowing your nose, after being out on a foggy day, how much soot and grime is filtered from the air as you breathe through your nose.

When you breathe through your mouth the air is neither warmed as much, nor filtered before continuing its journey to your lungs.

The windpipe leads from the back of the nose and the mouth down to the lungs, branching so that the air is divided between the two lungs. These two tubes divide and subdivide within the lungs, and at the very ends of the finest of these tubes are small air "sacs" or bags. The walls of these sacs are extremely thin but in them there are blood cells. Oxygen can pass through the walls of the sacs into the blood, and at the same time waste carbon dioxide passes through these walls out of the blood.

Do you remember why crowded and badly ventilated rooms are so very unpleasant? If you have forgotten think of the gases that you breathe out.

Have you heard of the "iron lung"? What is it and what is it used for?



YOUR FOOD HAS TO TRAVEL—

OUR bodies need food for two purposes; firstly it gives us heat and energy, and secondly it helps to build new bone and flesh as well as replacing the parts that are used up in our everyday life.

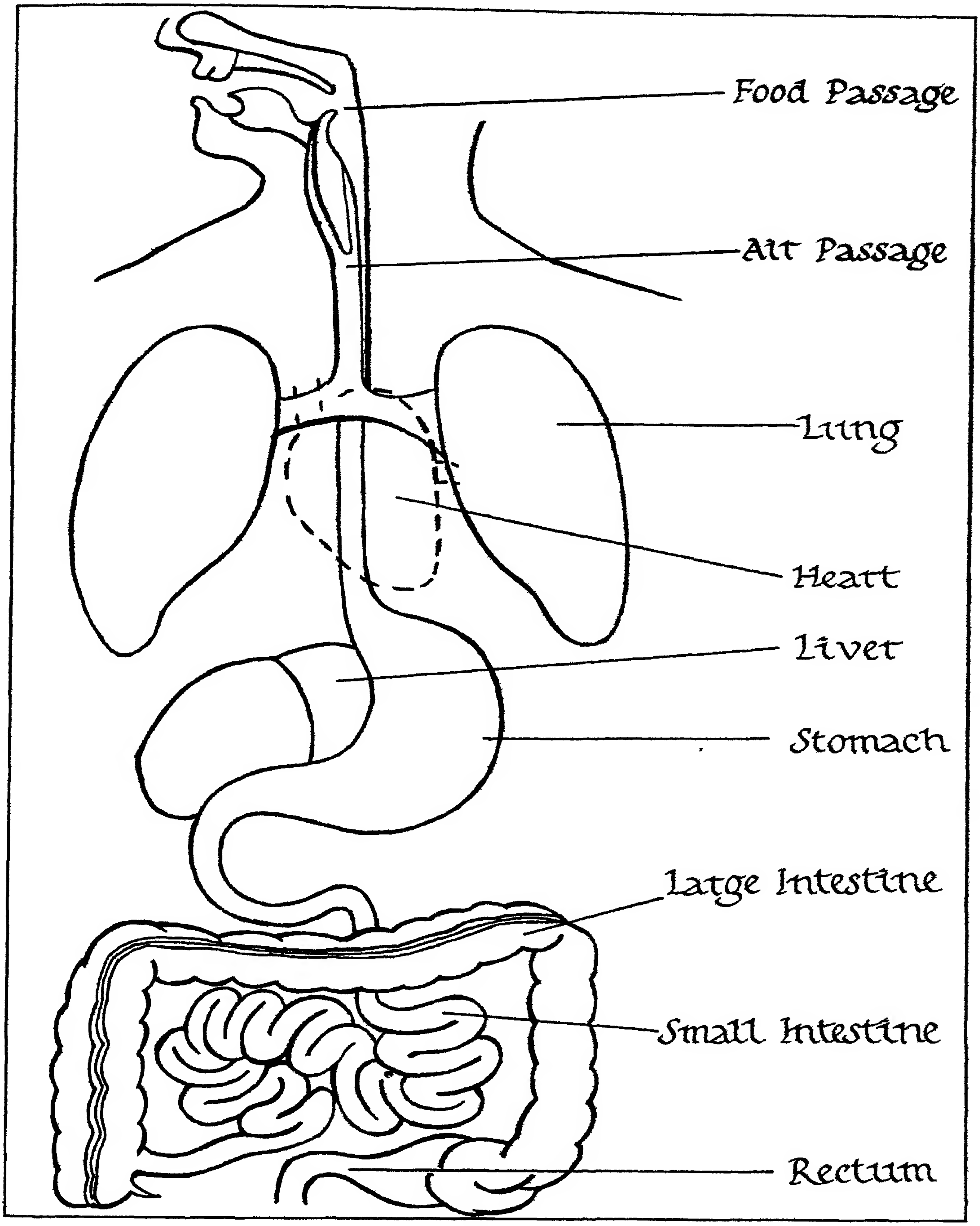
As you have seen the blood flows to all parts of the body, and it is the blood that carries the food. But the "food" which is distributed by the blood is nothing like the food that you eat. To be of use to our bodies food has to be changed, and some very complicated processes take place to make this possible.

With your sharp front teeth (do you remember their correct name?) you bite off some food, and then it is ground up by your back teeth. The tongue turns it and mixes it with saliva. Already the food has begun to change. It is then swallowed, the muscles of the gullet squeezing it down the tube which opens up in front allowing it to pass down, into the stomach. Here certain "juices" act on the food turning some parts of it (the proteins) into a soluble form. Then by a series of jerks, or contractions, the food passes through the small intestine, which is about twenty feet long, and so to the large intestine, which although larger, is much shorter, being about six feet long. As the food moves along more "juices" work on the food, so that by the time it comes to the end of the intestines all the digested food has passed out through the walls of the intestines, and so into the parts of the body that need it. Any unwanted food which is left after this is passed out as waste.

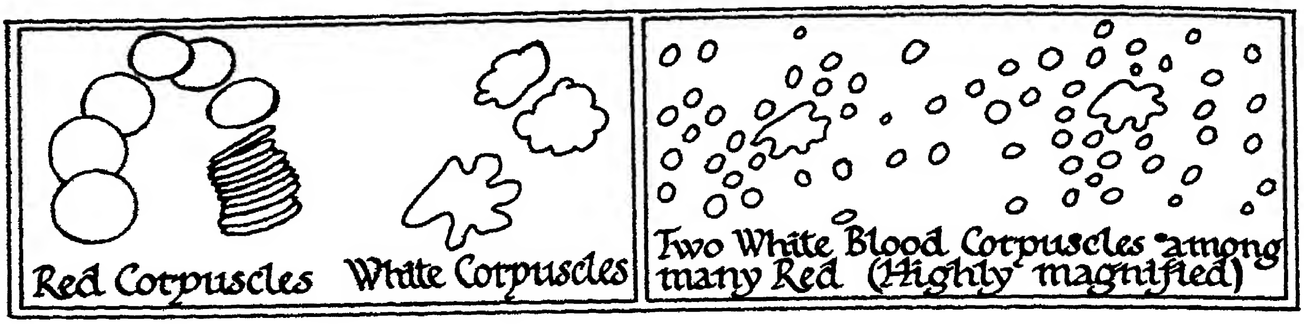
This complicated process is called digestion, and once the food has been swallowed the whole process is entirely automatic and we are rarely conscious of it. It is only when things go wrong that we become aware of it. When this happens we say we are suffering from indigestion, and this is caused when we eat too quickly, or sometimes when we eat food that is too rich, or sometimes when we eat too much.

When you breathe through your mouth, why doesn't the air go to your stomach? Why doesn't food that you swallow go into your lungs? At the top of the windpipe, there is a lid of cartilage, the "epiglottis". When there is some food or drink being swallowed this closes tightly so that the food passes to the stomach rather than to the lungs. Very occasionally food does "go the wrong way" and when this happens, we choke and cough, and this brings the food back again so that it can take the right path.

—A LONG WAY IN YOUR BODY



THE BLOOD HAS—



SO far we have thought and talked of the blood as a single substance, though you probably know that this is not so. The liquid part is called "plasma" and in it there are millions of tiny cells. They are known as "corpuscles" and some of them are white, but many more of them are red. We cannot see them with the naked eye, but they can be seen under the microscope, and the drawing shows you how they appear.

The blood has several important jobs to do, here are some of them:

1. The delivery of food.
2. The delivery of oxygen.
3. The collection of carbon dioxide.
4. The closing of wounds by clotting.
5. The protection against germs and the poisons they make.
6. The regulation of the body temperature.

We have seen how food eaten by us is digested and changed into a form that is of use. This food material is passed by the blood in the arteries to all parts of the body. When the blood passes through certain organs some of the food material is given up by the organs to be used either for building or for energy.

The red corpuscles in the blood contain a substance known as "haemoglobin". This material joins up with oxygen to form "oxyhaemoglobin". In this way oxygen is carried.

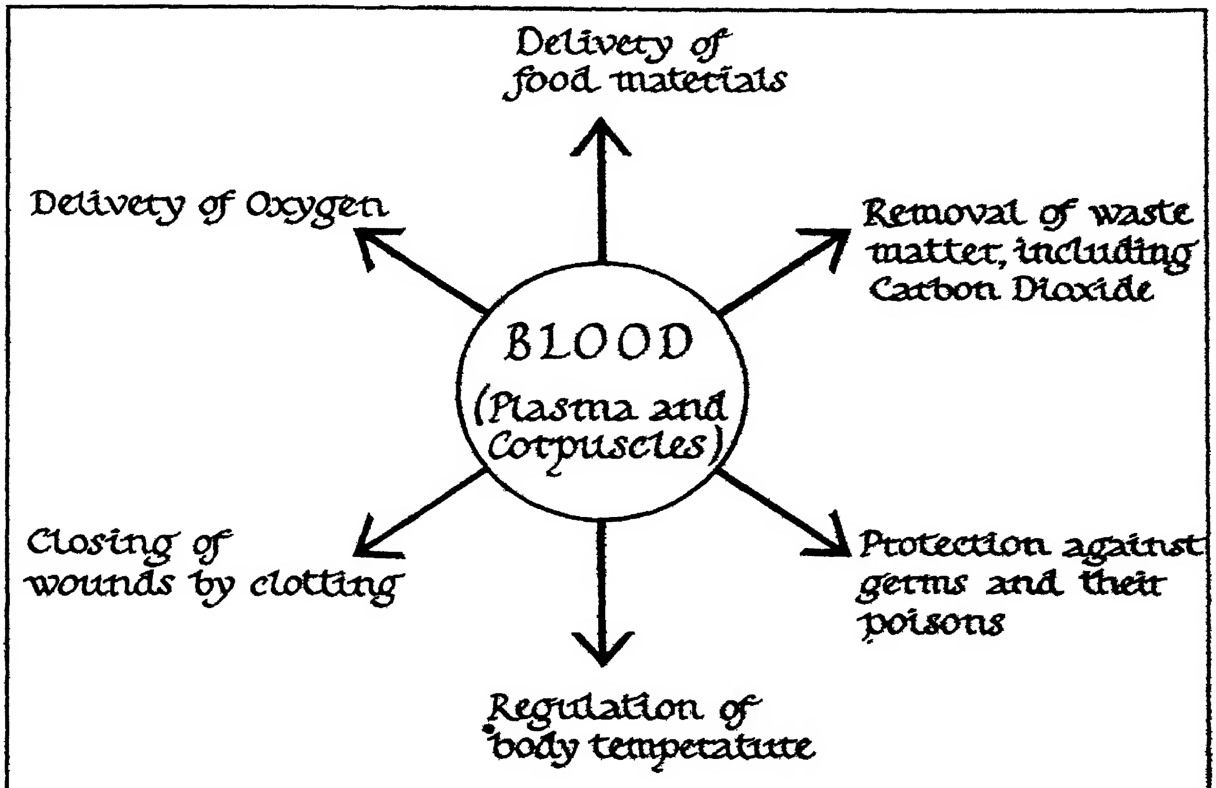
Energy is needed whenever you do anything, even when you are resting. We have seen that when fuels burn, energy in the form of heat is set free; when burning is slow, energy is given out slowly, and there is no flame. In the blood there is a fuel, our food. There is also oxygen. When these combine energy is set free and when you exercise violently the combination is speeded up giving you more energy. When food is changed into energy, waste products are formed and these must

—MANY TASKS TO DO

be got rid off. All our foods have carbon in them and carbon dioxide is formed when carbon "burns". This carbon dioxide is carried to the lungs and breathed out. Another waste product is water. Some of it is given up with the carbon dioxide in the lungs, some is lost by perspiration, but most of it passes through the kidneys and so out of the body.

Although oxygen combines readily with the blood, the poison gas carbon monoxide, which is found in coal gas, comes from coke fires, and is found in the exhaust gases of petrol engines, combines even more readily with the haemoglobin. This means that the blood-stream will carry the useless carbon monoxide instead of the vital oxygen. It is not dangerous when this happens in wide open spaces where the amount of oxygen is much greater than that of carbon monoxide, but in enclosed spaces it can lead to sleepiness and finally to death.

Can you suggest a first-aid treatment for this type of poisoning?



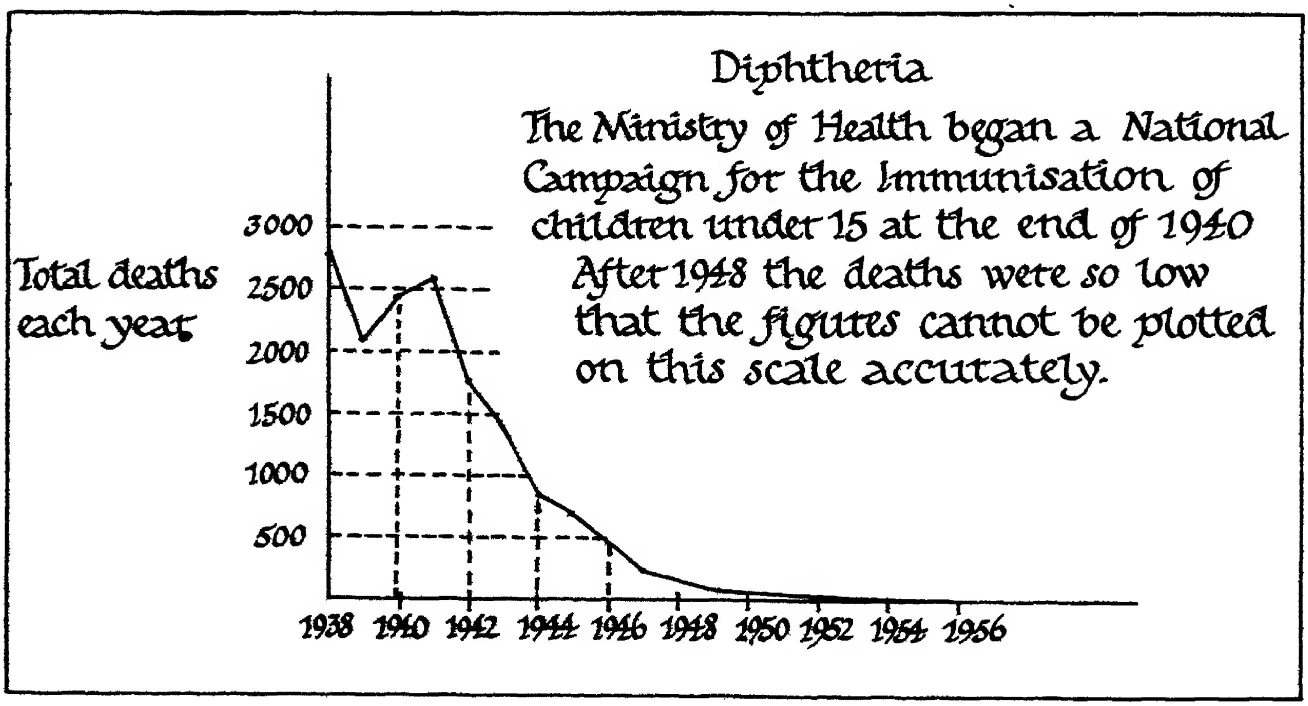
SOME OF THE IMPORTANT TASKS OF THE BLOOD

SOME MORE TASKS—

ONE of the wonderful things about the blood is the way in which it seals cuts and grazes. When you cut yourself, blood which is flowing quite freely suddenly changes its behaviour, as soon as it touches the skin or muscles. It begins to get sticky and finally dries up forming a scab. This process is called clotting. Although this closes the wound, if it is not too large, it is not a healing process for this goes on underneath, and the scab is cast off when the healing is complete.

Many diseases are caused by bacteria in the blood. The poisons that they produce will also be in the blood, and these are carried all over the body. These poisonous substances are often known as "toxins". The blood itself can make other substances that can neutralise these "toxins" and they are called "anti-toxins". The white cells also help to fight the bacteria that invade our blood-stream, but they use a different method. The white cells or corpuscles are larger than the red ones; they attack and swallow the bacteria.

Nowadays great stress is laid on the need for immunisation and vaccination. Do you know what they are? They are means of making a store of anti-toxins in the blood against attacks by certain bacteria. Find out more about these two preventatives and how they are used.

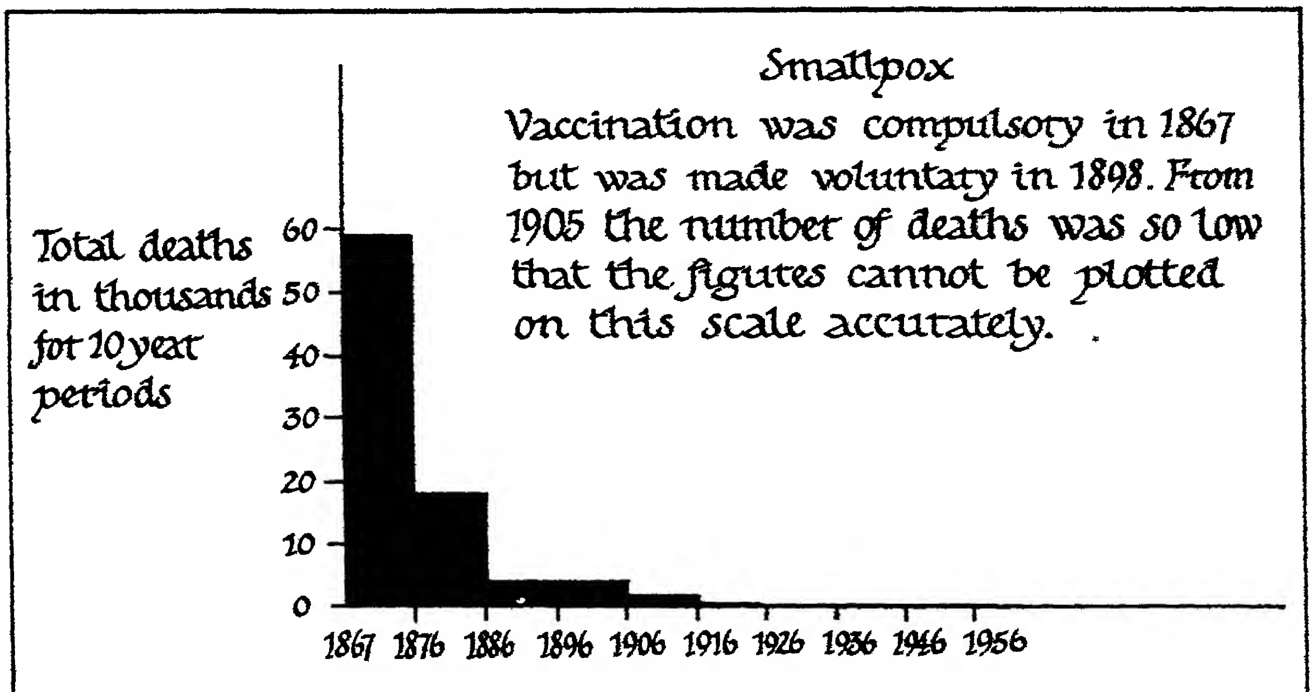


—FOR THE BLOOD

The graphs show you how successful these preventatives have been in practically abolishing two serious diseases, diphtheria and smallpox.

One of the advantages that Man and other mammals have over the other animals is that they can keep the temperature of their bodies the same whatever the conditions are like outside, so long as they are not unnaturally high or low. Man's normal temperature is 98·4° F. and, as he maintains this temperature, there must be some regulating device. On a hot day, he must lose heat to keep cool, whilst on a cold day he must generate heat to retain it.

When muscles are doing work they need a "fuel", and this is supplied by fats and sugars in our food. When these fats and sugars "burn" in the oxygen that the blood carries round, heat is produced. Even when you are resting, this process is going on slowly all the time. As we saw when we were dealing with the skin in detail, heat is lost by sweating, the amount of which can be controlled, and it is also lost from the capillaries in the surface of the skin, the amount again being controlled. All these tasks are carried out by quite a small amount of blood. Because of this, we cannot afford to lose large quantities of blood at one time, and, if a person does do so, then a blood transfusion may have to be carried out.



FIRST-AID TREATMENT—

IF you are a scout or girl guide, you probably know the first-aid treatment for cuts and minor wounds. But to remind you, or to tell you if you do not know already, here are the main things to do.

Bleeding can be of three kinds: it may come from an artery, and this can be serious, it can come from a vein which is also serious, while capillary bleeding, although not so serious, must not be neglected. All three kinds must be dealt with properly; and after first-aid, medical attention should be sought.

You can tell by certain signs the kind of wound you are treating. Blood from an artery is bright red and spurts out, blood from a capillary is red and generally oozes from a wound, while blood from a vein is dark red and flows steadily.

It is essential to know how to treat these wounds until help is available.

The patient must rest and not move more than necessary and a wounded limb must be raised unless bones are broken. If the wound is covered by clothing, it must be uncovered. Then press firmly on the wound while you make a pad from a clean handkerchief or some other clean material. Then bind the pad on firmly.

If, however, the bleeding is from an artery, and the pad does not stop the flow of blood, press with the thumbs or fingers on a point known as the pressure point, as near to the wound as possible, but on the heart side of the wound. Here the artery can be pressed against a bone underneath. By using a pressure point as near as possible to the wound, we avoid cutting off the supply of blood from more of the body than is necessary. If the wound is dirty, and you have some clean water, wash the wound, but remember that clotting of the blood is nature's way of stopping bleeding, so clotted blood should not be removed.

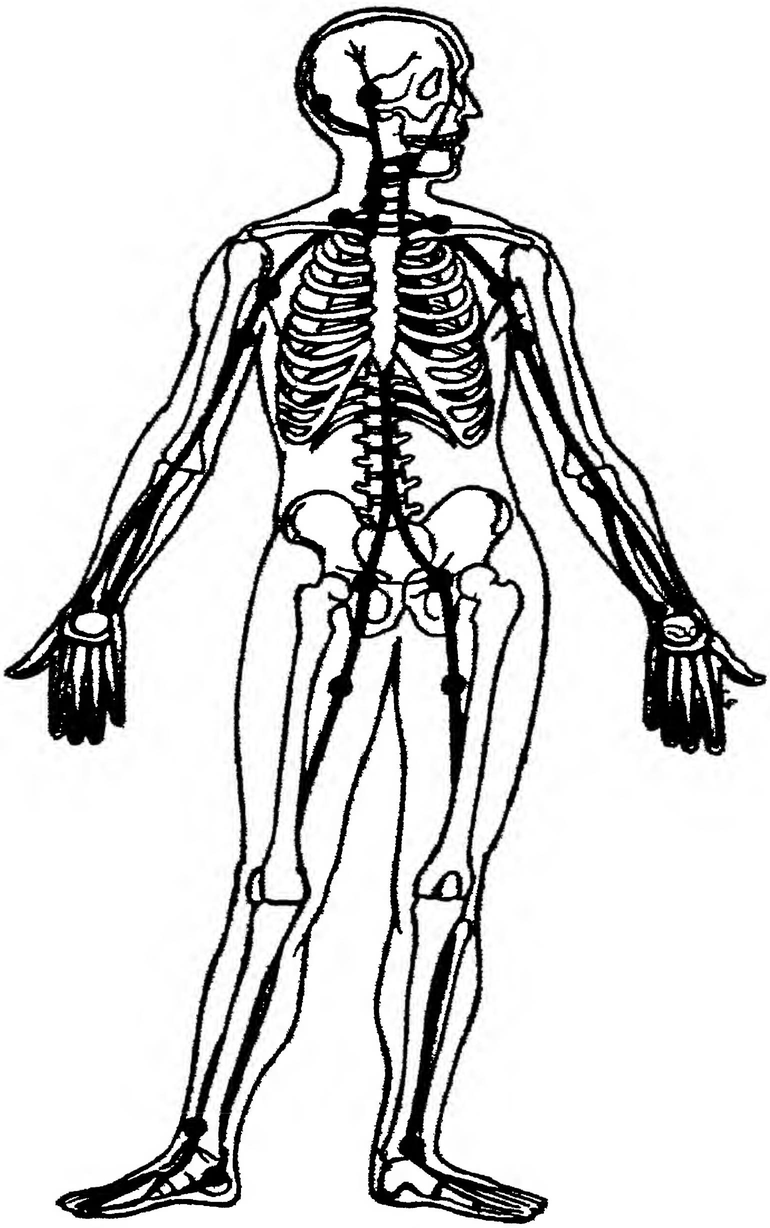
This is only first-aid treatment, and proper medical attention should be obtained as soon as possible.

Serious bleeding should never be neglected, and even minor cuts should be cleaned and covered.

Lastly, do not be frightened when you see blood.

If you had to make up your own first-aid kit for a camping holiday, what would you consider to be the six most important items for inclusion and why?

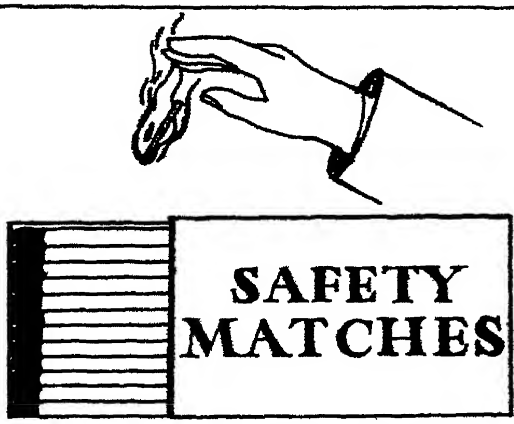
—FOR CUTS AND MINOR WOUNDS



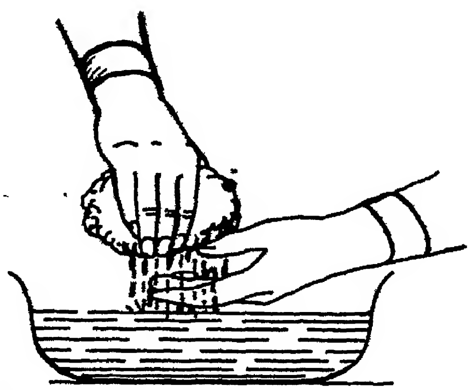
Pressure Points

Press with the thumb or fingers on the pressure point nearest the wound on the heart side to cut off the circulation

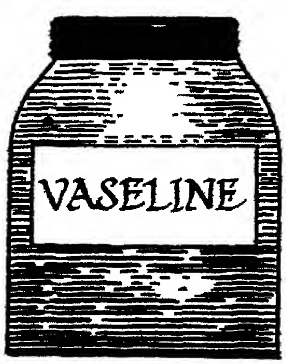
FIRST-AID—



1 Don't play with them



2 Bathe with warm water though not essential



3 Smear on a little Vaseline

THERE are two types of burns. One type is caused by dry heat. This happens when you grasp a piece of hot metal, or perhaps accidentally touch a fast-turning wheel. The other type of burn is caused by scalding, for instance when boiling water is spilled, or when you accidentally put your hand in the steam from boiling water. In both cases the first treatment is the same.

The skin carries out several tasks, and one of the most important is to keep harmful bacteria from entering our bodies. If the skin is cut or broken in any way, bacteria can immediately enter, and when the skin is burnt it often breaks; so part of the treatment for burns, or for any wound, is to stop this happening.

Burns can vary in severity. A mild burn will merely redden the skin, and although it may be extremely painful at the time, the skin does not break. A more severe burn will cause some blistering and reddening of the surrounding skin, and the worst burn of all will destroy the skin and the tissues beneath it.

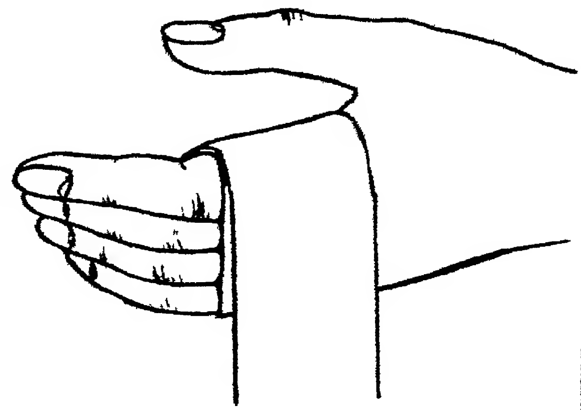
The best thing to do in the case of a mild burn is to cover it with a clean bandage, or handkerchief. If it is available a smear of Vaseline can be put over the burn first. This

may lessen the pain, but it is not essential.

Where there is blistering, on no account should the blisters be broken, they must be left for the doctor or hospital to treat. But, until such medical attention is obtained, the burn can be lightly bandaged.

In the case of the worst type of burns medical treatment is essential and time should not be wasted on elaborate treatment beforehand. Make sure that bacteria cannot enter the wound by covering it with some clean material, a handkerchief or a towel. Sometimes pain can be lessened by holding the burnt part in clean lukewarm water before covering, and the covering can be moistened with clean cold water. But the important thing to do is to get medical attention.

Burns have long been one of the doctors' most difficult problems. However, within the last few years an effective but simple system of treatment has been developed. Relief of shock, large amounts of blood plasma, simple dressings, blood transfusions to keep up the patient's strength and to prevent anaemia, and drugs such as penicillin to prevent infection, followed by skin grafts, all play their part in lowering the death rate and in speeding recovery from severe burns.



4 Bandage

5 If serious phone the Doctor

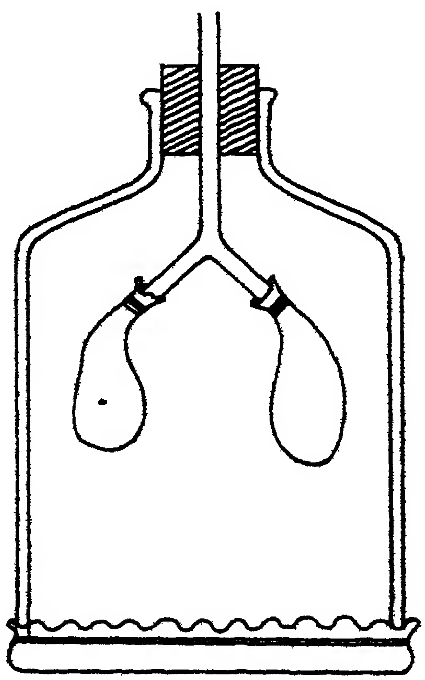
DO NOT BREAK BLISTERS

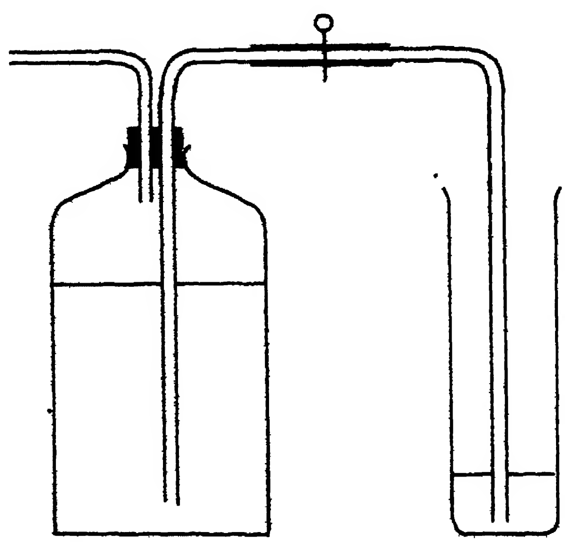
SOME SIMPLE EXPERIMENTS—

Although it is sometimes a little difficult, without elaborate apparatus, to do experiments that are concerned with the human body, there are one or two that can be done, using simple things. As with so many other experiments it will be helpful if you can work together in small groups of two or three.

1. When the diaphragm descends and the ribs rise, air passes in through the windpipe to fill the lungs. This action can be shown roughly by the piece of apparatus illustrated. Two balloons are fixed to the ends of a "Y" tube. This is inserted in a rubber bung in a bell jar, the bottom of which has a piece of sheet rubber tied on tightly. What happens when the rubber sheet is moved in and out? Is this a good picture of the action of the ribs, lungs and diaphragm?

2. Fix up the piece of apparatus as shown in the right-hand diagram. Now breathe in deeply and then breathe out completely through the tube forcing out an equivalent volume of water into the jar. This will give you a measure of the capacity of your lungs. Compare this with the results your partners get.





Remember to close the clip when you have finished blowing. Why?

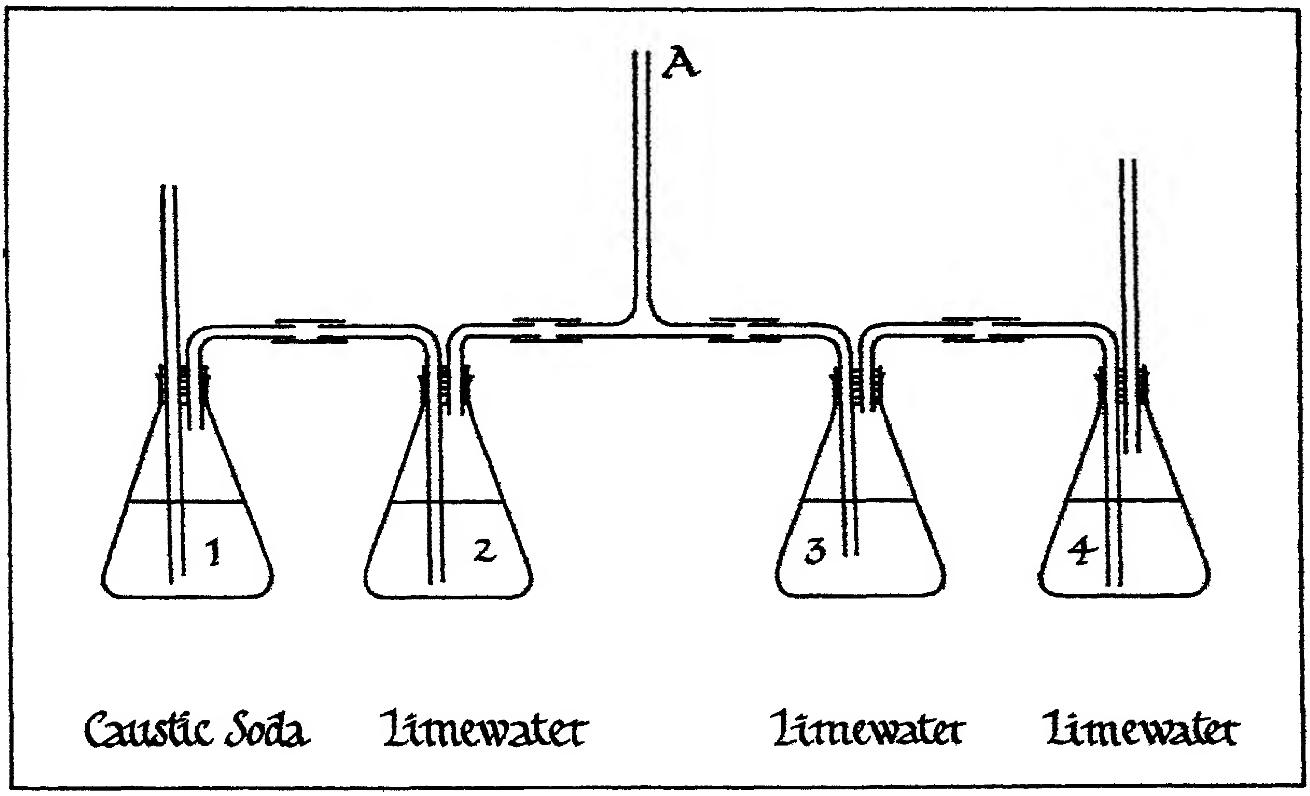
—IN BREATHING AND THE PULSE RATE

3. Breathe in and out through the tube "A" of the apparatus shown in the next diagram. The caustic soda in the bottle on the left removes the carbon dioxide in the air, so that the limewater in bottle 2 stays clear. Air that is breathed out is passed through bottles 3 and 4. The limewater in them soon becomes milky. What does this show?

4. Take the pulse of the various members of your group, using the artery in the wrist below the thumb, while the palm of the hand is face upwards. Repeat this after the "patient" has done some arm exercises.

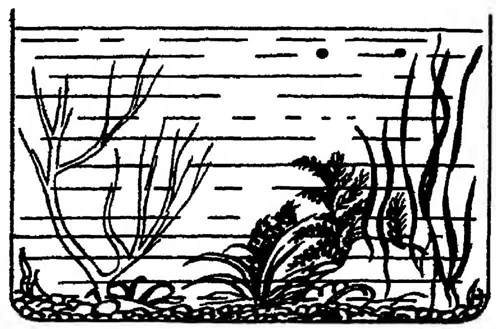
5. Clench one of your fists and let that arm hang downwards. Now stroke firmly with the other hand towards the wrist. Can you see any small swellings in front of your wrist? These are the valves in your veins.

6. Put some saliva in a test-tube and dilute it with a little water. After adding a little starch solution to it, divide it between three test-tubes. Test the first tube shortly after for starch, the second one after two or three hours, and the third one very much later. What do you see? How do you account for it?

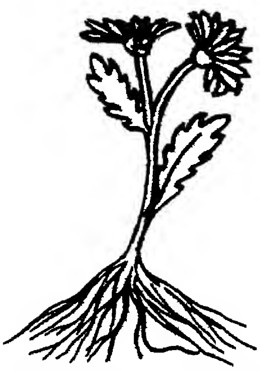


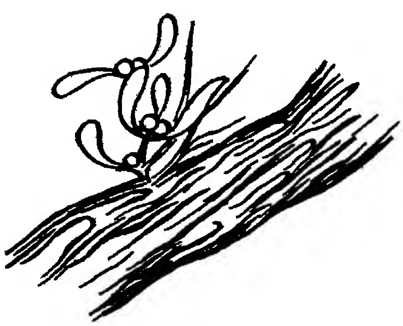
ALL PLANTS HAVE—

JUST as with animals, plants have simple needs that must be satisfied, if the plant is to remain alive and to grow. Do you remember what the simple needs of animals are? How many of them apply to plants too?

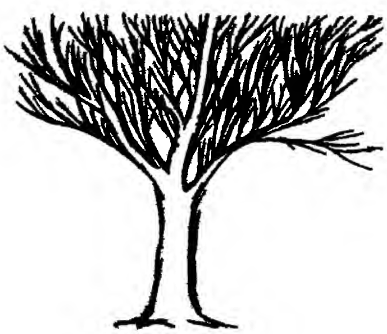


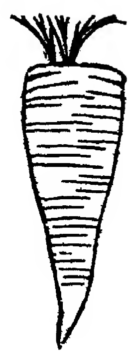
Plants need oxygen and carbon dioxide Where does it come from?

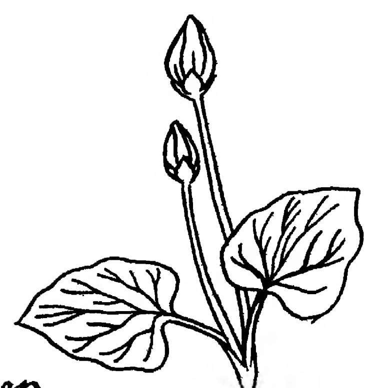




Plants need food and water Where does it come from?



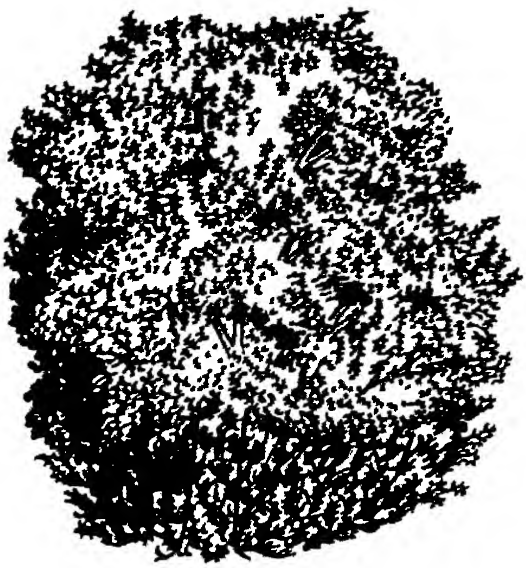




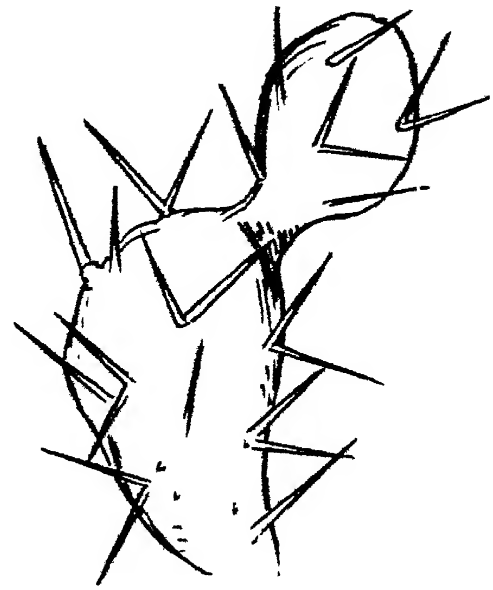
Plants need rest and sleep

—THE SAME NEEDS

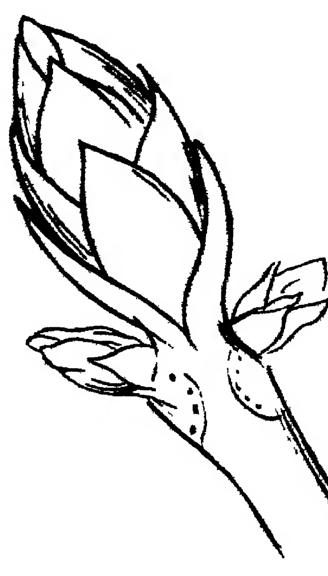
As with animals, some of the needs are more important than others; where the need is vitally important and cannot be satisfied, the plant will die very quickly. These needs are few in number and although all plants must satisfy them, they are often satisfied in different ways.



Plants need protection



Do you know any other ways?



Plants need a covering

THE PARTS—

WE have studied the "make-up" of the human body in some detail; had we studied an animal such as the rabbit, we would have seen that it is much the same. All animals with backbones, such as fish, frogs, snakes, birds, and mammals have the same general construction, though of course there are variations. They are known as vertebrates. Some have wings, some walk on two legs, others on four. All need oxygen, but some get it from the air, others from air dissolved in water. A plant, on the other hand, has quite a different structure.

While we are talking about the main parts of a plant, it will help to have one in front of you. It will be better too if you each have a different plant, and maybe you would like to work in groups of two or three. At most times of the year it is possible to find some flowers, even if they are only the uncultivated ones that grow on waste ground. Don't pull the plant up roughly, dig it up carefully, and then gently wash the soil from the roots.

Make a list of the main parts of an animal, for example the head, the heart and so on. Now look at your plant. How many similarities can you find between the plant and the list you have made? At once you will see that a plant has a completely different construction from an animal. But, just as each part of the animal has an important part to play, so has each part of the plant. Can you identify the main parts of your plant?

Starting at the base there is the root. No doubt some of you have seen the shoot that emerges when a bean seed begins to grow. This shoot is called the "radicle". This radicle gradually grows longer and longer, and small roots emerge from it. This long root is called a "tap root". When the side roots are as long as the main root, we say we have a "fibrous" root, while the roots that come from bulbs are called "adventitious", because they come from the base of a stem, in this case, the bulb which is an underground stem.

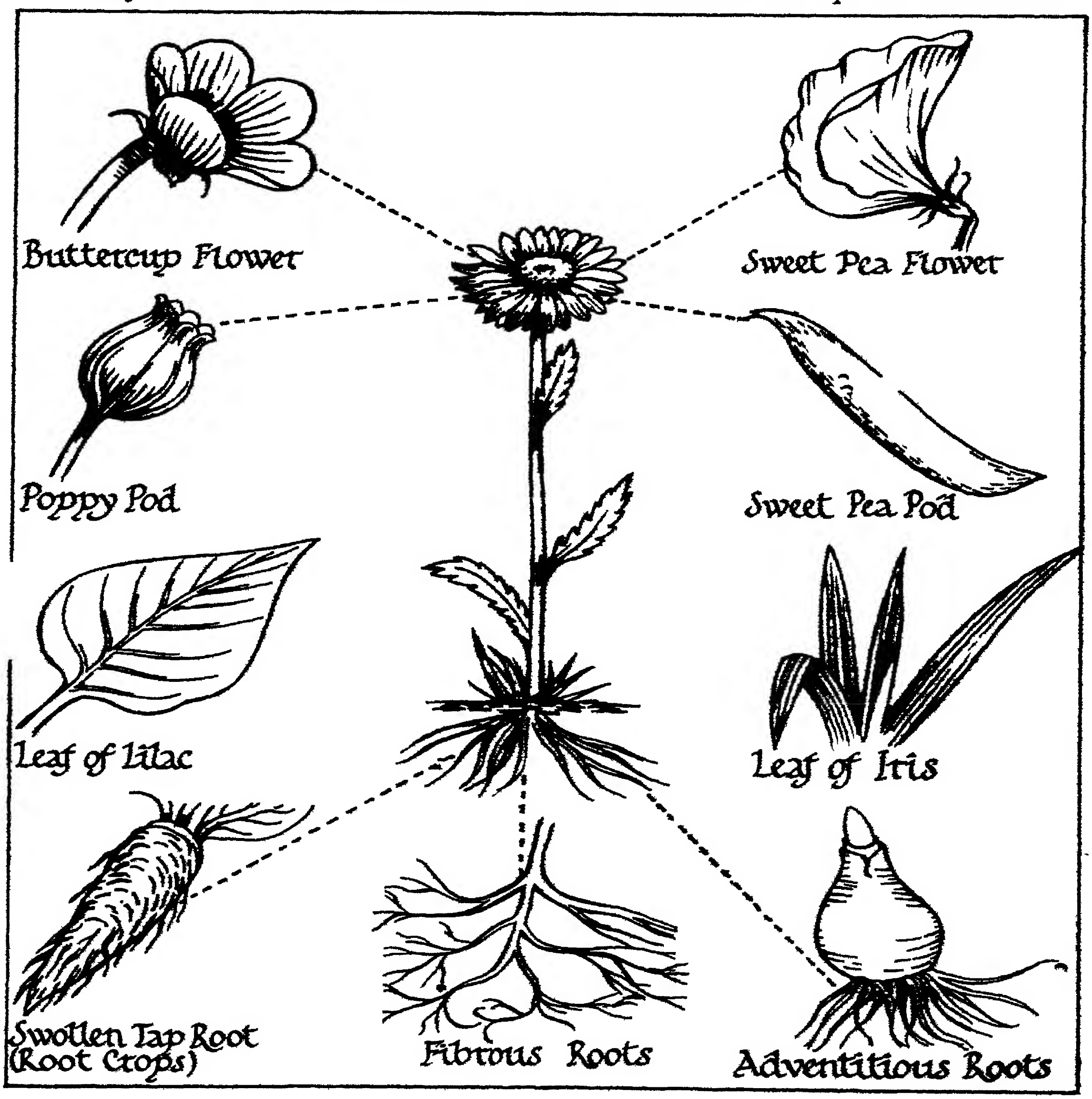
Above the soil level we have the stem. This may branch immediately above ground level, or may branch some way above the ground, or even may not branch at all. Usually branching occurs repeatedly, just as with the roots, and at the tip of each stem there is often a bud. Leaves grow at intervals along the stems, in a definite order, and not just anywhere. There are two main parts of a leaf, the leaf stalk and the blade, or "lamina" as it is called. In the lamina we can see the

—OF A PLANT

system of veining. Sometimes the veins branch, and sometimes they run parallel.

At certain times of the year the plant has flowers, and from them come the fruits and seeds which give new plants to replace the old which die off.

Why is there this difference between animal and plant structure?

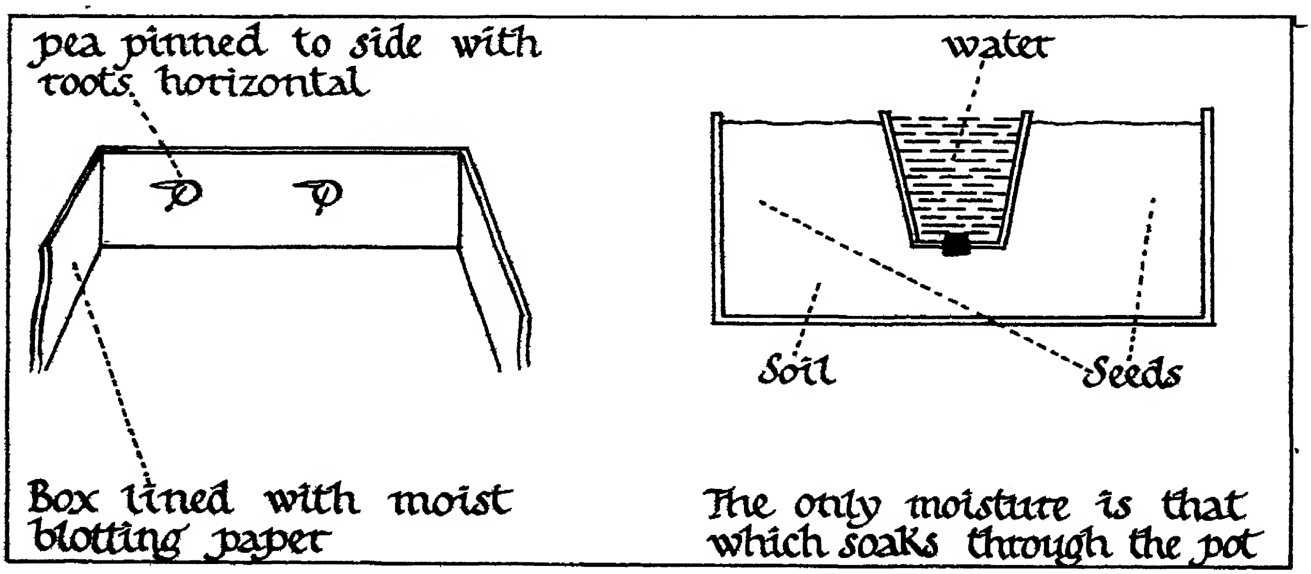


A PLANT MUST—

THE roots of a plant carry out three main functions. First to act as an anchor in the ground, secondly to take in water and food for the plant to live on, and thirdly, sometimes, as a store of food that has been made by the leaves. If you study through a magnifying glass the roots of a plant, from which all the soil has been carefully washed away, you should be able to see a mass of tiny root hairs. It is through these that water enters the plant. To do this the roots must grow downwards into the soil where water is stored. If you can grow some mustard seed on a damp piece of flannel or rag, quite soon you will see the roots growing into the material, and these you can examine under your magnifying glass.

Soak some peas or beans in water until they become swollen. Now plant them in moist sawdust in jam jars, or better still, flower pots. After a few days you will be able to remove them without breaking the roots. Let them grow until they are about an inch long. Line a box with moistened blotting paper and pin some of the beans or peas to the side of the box so that the roots are horizontal, as in the diagram. Cover the box and leave it on one side for a day or two. When you next look you will see that the root tip has turned and is once again growing downwards.

Now we will show that roots grow towards moisture. Fill a wooden box with soil which is almost dry. In the centre sink a small flower pot, first corking up the hole at the bottom. Around the edge



—AND A PICTURE QUIZ

refer back to your books. Fill in the gaps in pencil first. When you have done this check your answers, and you can then ink in the correct words. Do not worry if you cannot make your flowering plant and your human body perfect, but it is important that the parts marked are in the correct positions. Do not mark this book in any way.

Light and warmth are needed for ----------------

Stamens are ------------ ------------

Insects help the flower by ----- ---------------

Plants do not move because. ---------------

Water enters through ------ ---------------

Flowers are coloured because ----------------

Insects come to collect -------- ------------

Plants have no digestive systems because ----------

Plants need leaves for making ----- ----------------

Some plants such as -------------- store food

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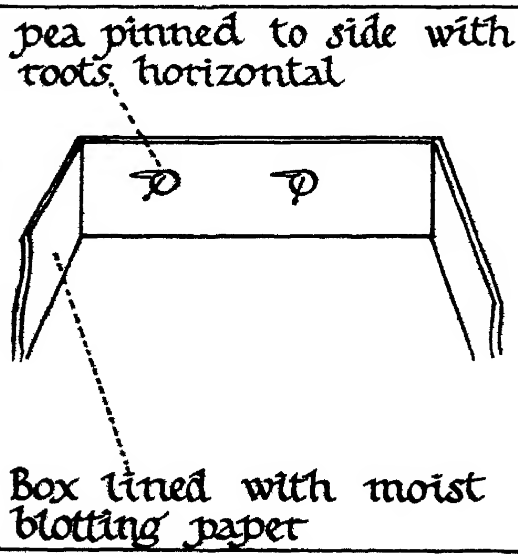
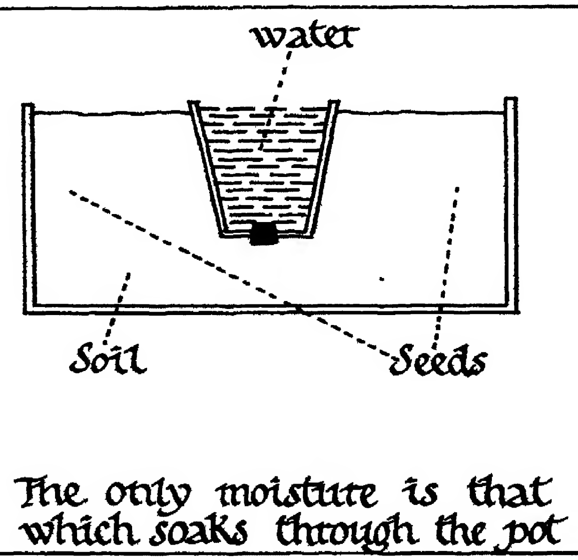




of the box plant some peas that have first been soaked in water. Fill the flower pot with water. Keep the flower pot filled with water, but do not water the soil in the box. In this way the only water that the plants can get will be that which will seep out through the sides of the unglazed pot. After two or three weeks carefully dig up the seeds. In which direction are the roots growing?

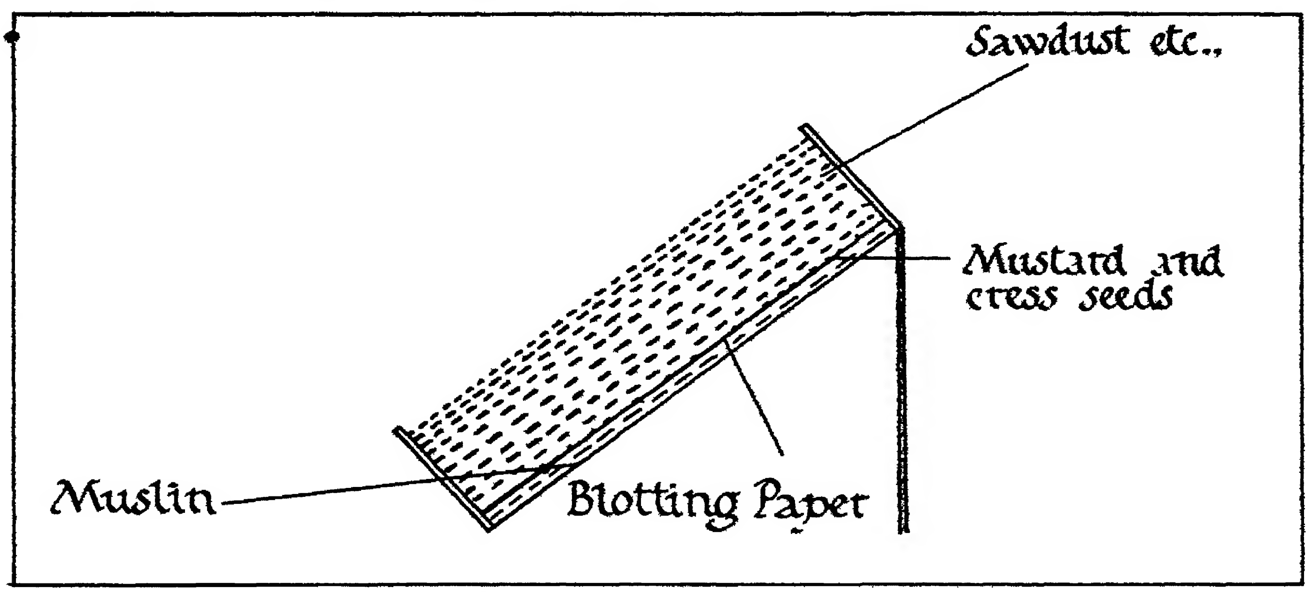
Make a fine sieve by stretching a piece of muslin over a wooden frame and tack it down. On the muslin put a thin layer of sawdust and scatter some mustard and cress seeds on the sawdust. Cover the seeds with a piece of moist blotting paper and another layer of moist sawdust. Prop your sieve up at an angle of 45° as shown in the diagram, and keep the sawdust on the top moist. After a while you will see the roots come through the sieve, growing downwards, and then gradually they will turn. Which way do they turn and why?

We have said that the food of a green plant consists of three things: carbon dioxide from the air which is taken in by the leaves, water and dissolved mineral salts taken in by the roots. We know that water can pass from the roots to the leaves, and that it passes into the roots from the soil; why is it that the reverse does not happen, that is, water passing out of the plant into the soil?

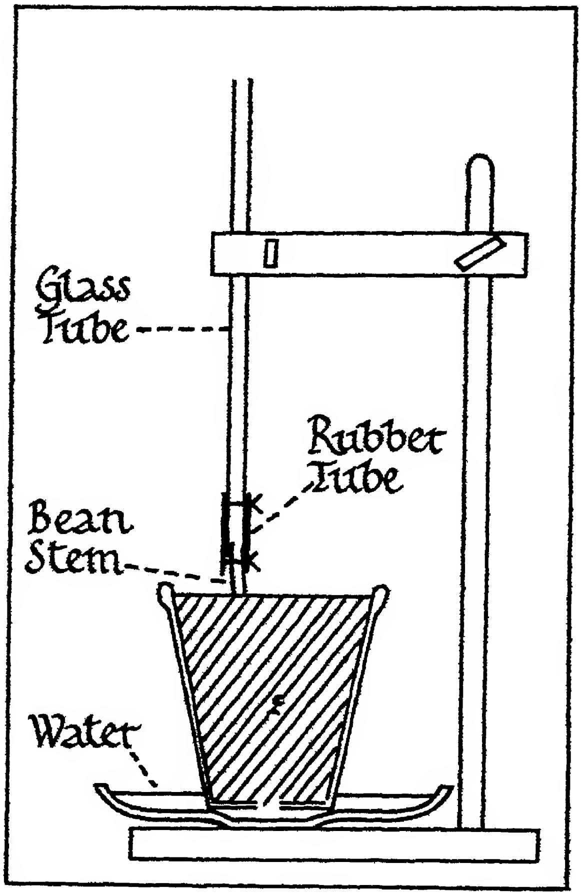
Can you answer these questions?

(*a*) What is root pruning and why is it used?

(*b*) What is tip rooting?



THE MOVEMENT OF WATER—

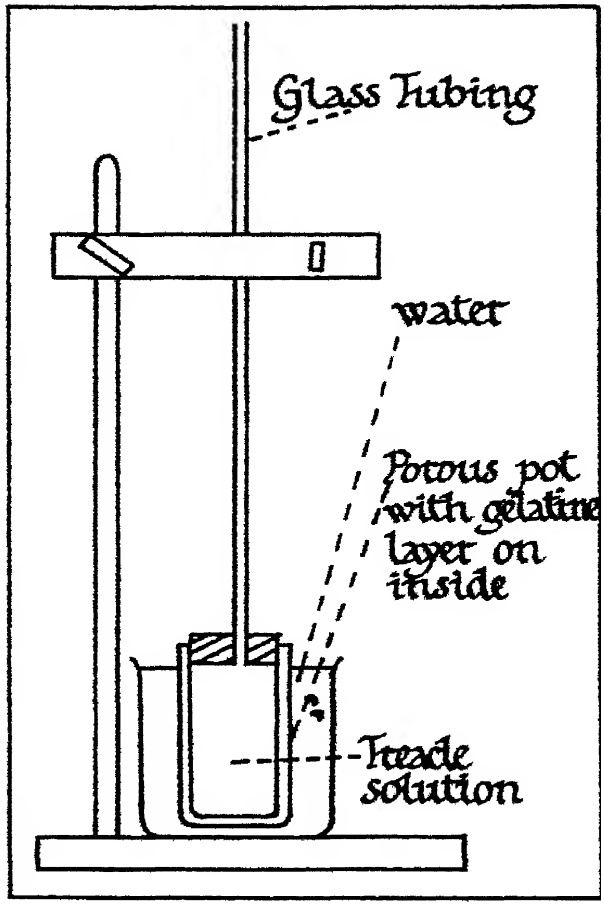


PLACE a few sultanas and currants in a little water and leave them on one side for a day or two.

Plant a scarlet runner bean in a pot and allow it to grow until it has several pairs of leaves. Cut off the shoot about two inches above the level of the soil, and below any leaves. Attach a piece of glass tubing to the cut stem by means of some rubber tubing. Stand the pot in a saucer of water, and look at it each day. After a time you will see water rising in the glass tubing. You can if you like do this experiment using a geranium plant growing in a pot.

What can you say about this experiment, and about the fruit left soaking in water?

Here is an experiment that will help you to understand this movement of water. Warm some gelatine in water in a beaker, and then add a little glycerine to this solution. Tip the solution into a porous pot and swirl it round so that the inside is coated with the solution. Tip back the surplus into the beaker. When the pot is dry do this again, so that you have a double coating of the solution in the pot. Make up a strong solution of treacle in water and fill the pot. Fit a rubber bung with a glass tube as shown in the diagram, and stand the pot inside a trough of water. After a few hours the water level inside the glass tube will have risen, and, if the gelatine has been applied properly to the inside of the pot, it should continue to rise for several days. As the water enters the treacle solution, the solution becomes more and more dilute. It is easy to get the solution to rise as high as ten or twelve feet if your tube is long enough. We call the layer of gelatine a membrane; water can pass through it, but only a very little treacle. This passing of water through the membrane is called "osmosis". By the



process of osmosis water passes from soil into the root hairs and into the cell sap in the root hairs. In our experiment the treacle solution represents the cell sap. In the plant, cell sap cannot pass out of the root hairs, but water can pass in, taking in dissolved mineral salts with it, so that it is not pure water that enters. Of course, unlike the pot we used, the plant has a means of controlling the amount of water that enters.

You will remember how water with red ink in it rose through a flower until it reached the petals, and how moisture appeared on the glass jar when a plant in a pot was covered with it. How does the water rise in a plant? Just as paraffin will rise between the spaces in the fibres of a lamp wick, so water will rise in the narrow spaces inside the plant. We called this capillarity. The rising of water in a plant is helped by the evaporation of water that passes out through the leaves, for more water rises to take its place. But there is another force that helps water to rise in plants. You may have noticed drops of water on the leaves of plants in your garden in the morning after they have been watered the night before, especially if the night has been a warm one. In warm sultry weather roots send up water and because the atmosphere is moist evaporation does not take place, and water is forced out of the leaves in certain places by this root pressure.

Can you now explain why the water has risen in the tube above the cut stem in your earlier experiment? In the experiment with the treacle solution in the porous pot, the solution as it was diluted rose in the tube to a height of several feet. What factors govern the height to which the water rises?

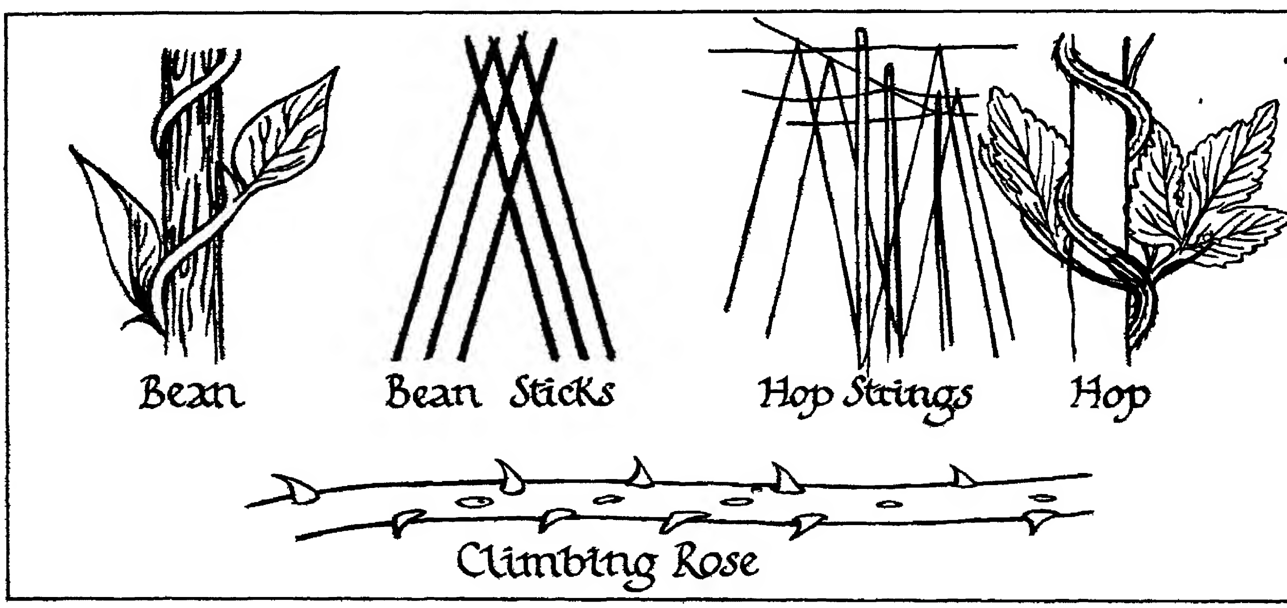
STEMS THAT—

BETWEEN the roots in the ground and the leaves there is the stem. What are the tasks that the stem has to perform for the plant as a whole? Think of water and the food of plants.

All stems carry leaves, and in the angle between the leaf and the stem buds which are the future branches often appear. On some plants, as we have seen already, the stems are underground. We mentioned four types of underground stem; rhizomes, bulbs, corms and tubers. Can you remember any examples of such plants? Here is a list of plants; can you say what types of stem they have? Crocus, onion, potato and iris.

Some plants have stems that creep along the surface of the ground, the strawberry for example. Do you know the name of another plant that has this type of stem?

There is yet another kind of stem; examples of this are shown by the hop plant and the runner bean plant. Both have weak stems, and since the plants must grow up towards the light, the stems climb and support themselves by twisting round whatever support or suitable object they can find. Of course, the cultivated plants are given supports, as you may have seen in the hop fields and in the bean rows which you probably have in your own garden. The convolvulus is another climber. The stem of the bean can hold on to its support because of its roughened surface, but the convolvulus twists so tightly



—TWIST AND CLIMB

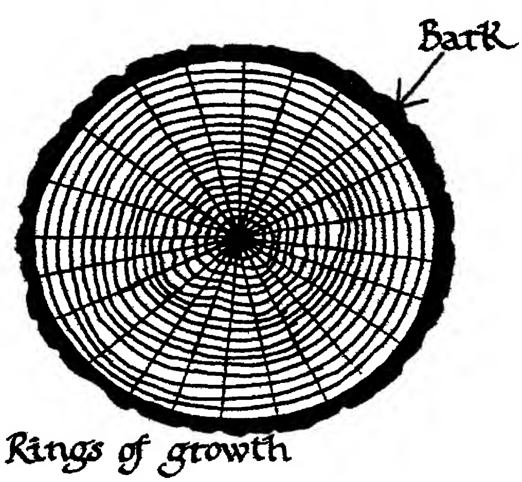
that it needs no help. The hop, on the other hand, has tiny hairs on its stem that act as hooks so that it can get a good grip on the support.

How do the bramble and the rose manage to hold themselves up?

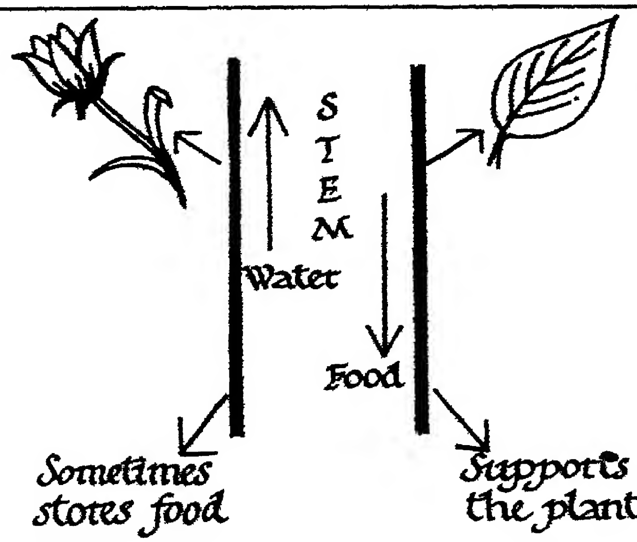
Have you ever looked carefully at the stump of a tree that has been cut down? What are the things that you remember most clearly about it? Among the tasks of the stem of a plant is the carrying of food and water, as well as the supporting of the weight of the branches and the leaves; so that, whereas a small plant such as the buttercup can manage with a soft stem, trees have much tougher and harder materials in their stems. However, although the wood may be very hard, it must still be able to "give" in a high wind. Each year, a fresh layer of wood is formed and if you count the rings when a tree is felled, you can tell how old it is. What is the purpose of the bark on a tree?

Can you answer these questions?

1. What is "ringing" a tree?
2. What does ringing do to the tree?
3. Why is wire netting sometimes put round the base of a newly planted sapling?
4. How can a hollow tree go on living?
5. Where does cork come from?



Section of a tree



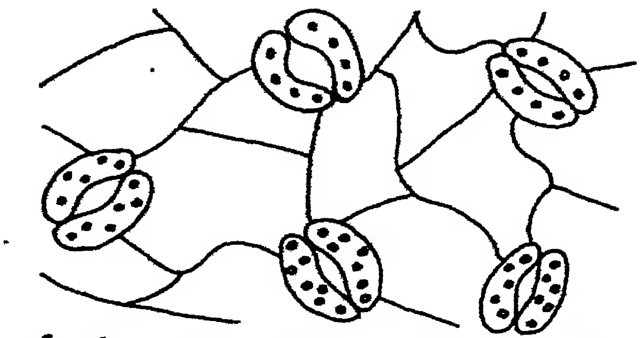
The stem has many tasks

LIGHT IS NECESSARY—

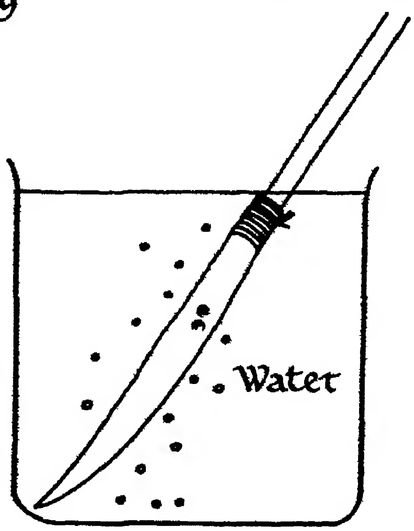
DO you remember how when we grew plants away from the daylight they became long, spindly and whitish in colour? If a plant is kept without light for too long it will die. Bulbs in pots for indoor decoration are often started off in the dark, and only become green when they are brought into the light. Rhubarb is sometimes "forced" so that the stalks are long, but neither the stalk nor the leaves are the natural colour. Celery is "blanched" by heaping the earth around the growing stalks and so keeping away light.

Collect several leaves from different plants. Boil some water, and remove it from the heat. With tweezers plunge the leaves one at a time into the hot water. What happens? Try using an onion leaf if you can get one, and blow down the hollow centre. You will see air bubbles escaping from the leaf into the water. Now look at the diagram, this shows you even more clearly that air can enter and leave a plant through the leaves.

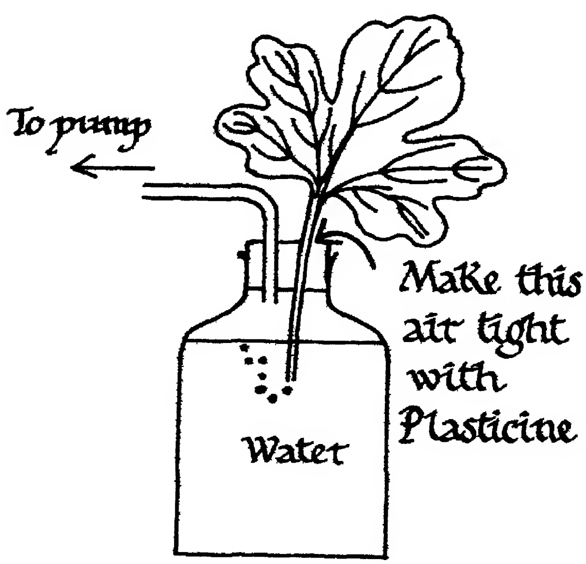
We know that plant foods contain carbon, hydrogen and oxygen and that such foods are called carbo-hydrates. Starch is a carbohydrate. Green plants are only green when they grow in light, and light is required so that plant food can be made. Can you see how these two facts are connected?



Surface view of lower epidermis of a leaf



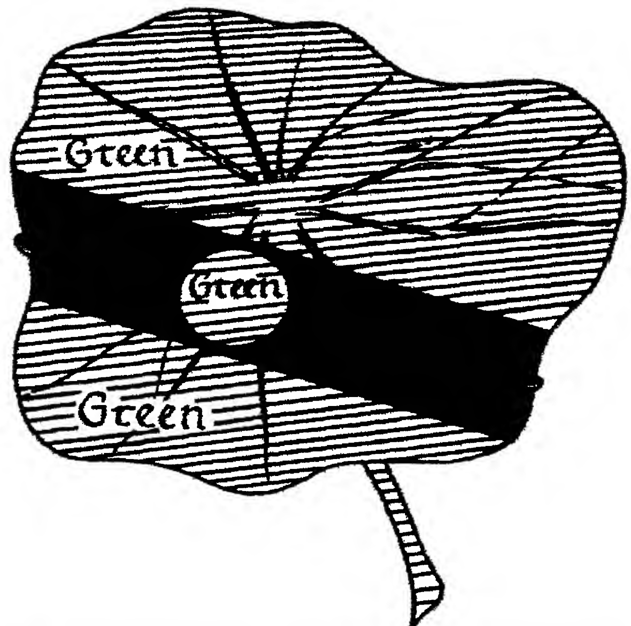
Onion leaf tied to glass tubing



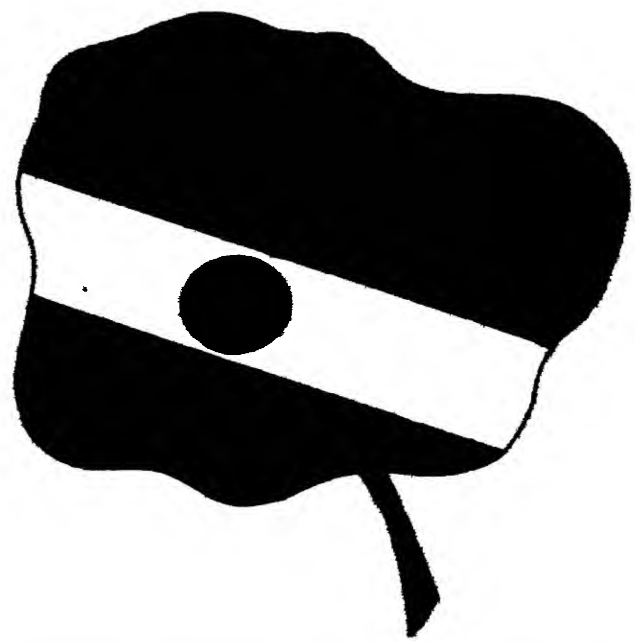
—FOR STARCH FORMATION

In the laboratory, scientists make "tests" to show if certain substances are present. When iodine is added to starch it becomes a blue black colour, and this is the test for starch. Take some green leaves from a plant and first plunge them in boiling water and then soak them for a while in methylated spirit. This will allow the green chlorophyll to dissolve out. Dry a leaf with blotting paper and add a little iodine solution to the leaf. A deep blue colour is seen. Repeat this experiment with leaves from a plant that has been growing in the dark for some days. Is there any starch present in these leaves? Look at the diagram. A piece of black paper is fastened to the leaf of a growing plant which is then left in the light for a few days. Repeat your test for starch on this leaf. Is starch present in the leaf? Everywhere?

Some plants have leaves that are green only in patches. Privet is an example of this. These leaves are called "variegated". Do your test for starch on some variegated leaves. Is starch formed in the green part where there is chlorophyll, or in the non-green parts? From these experiments we can see that both light and chlorophyll are necessary for the making of starch in a plant.



Nasturtium leaf with black paper pinned on

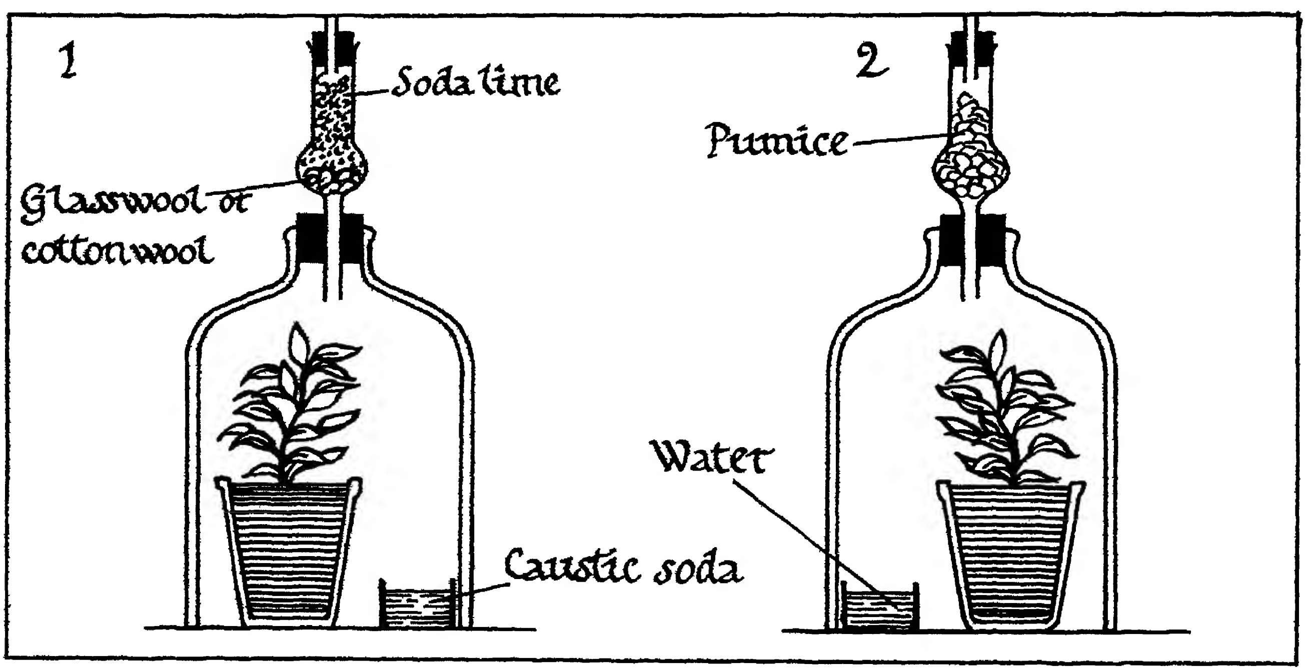


Iodine shows where starch has been formed

STARCH is made by a plant from carbon, hydrogen and oxygen. Hydrogen and oxygen are provided by water, and carbon dioxide from the air provides carbon and oxygen as well. But does the plant take carbon from this source?

To show that carbon dioxide is necessary for starch formation we need the apparatus shown in the diagram. You see that there are two pieces of apparatus with a small but important difference. In one soda-lime and caustic soda will remove carbon dioxide from air entering the bell jar, while the pumice will not; and water does not contain it. Two plants that have been growing in pots in the dark are put under the glass jars. Why have they been left in the dark first? After the plants have been in the light under the bell jars for some time take a leaf from each and test for starch. The leaf from the plant in the jar where carbon dioxide is allowed to enter has formed starch, while the leaf from the other bell jar, where no carbon dioxide can enter, has no starch.

Since both water and carbon dioxide contain oxygen there must be a lot of unwanted oxygen. What does the plant do with it? Put some pieces of Canadian waterweed under a glass funnel. Stand this in a large beaker of water and after filling a test-tube with water place it over the end of the funnel as shown. Leave this in the sunlight and



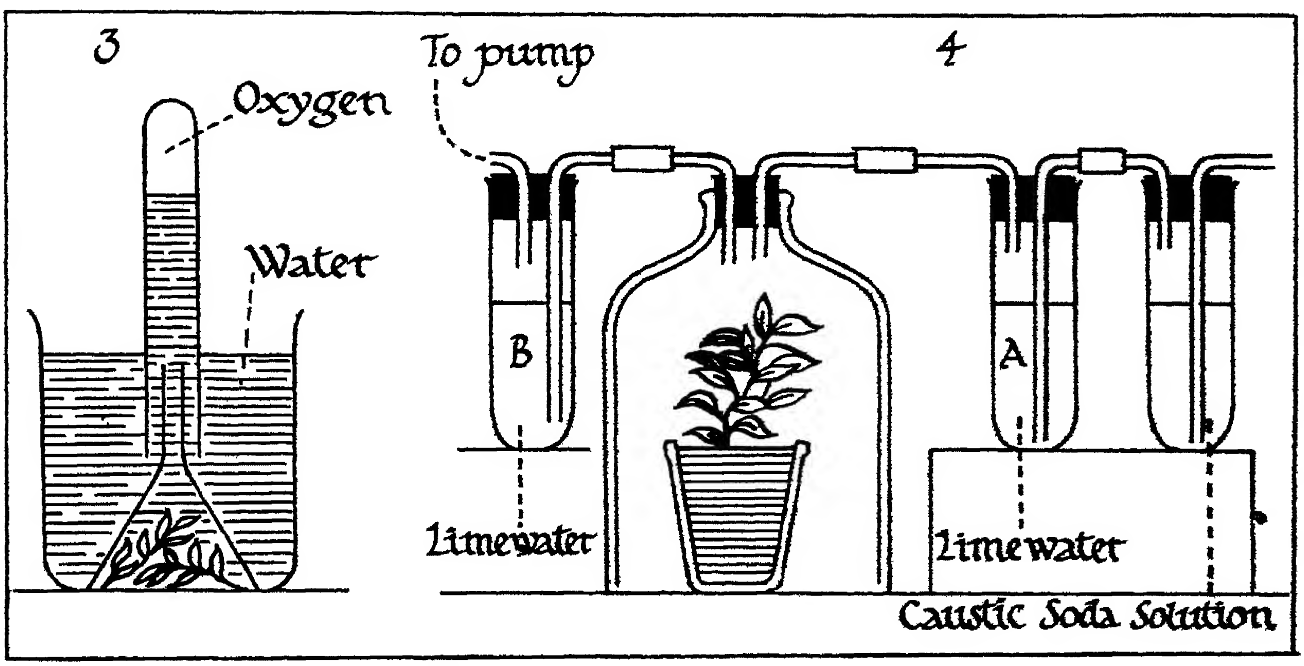
—AND RESPIRATION IN A PLANT

you will see bubbles of air coming off. After several days test this gas with a glowing splint, a test for oxygen.

Thus we know that a plant converts carbon dioxide and water into sugars and starch, liberating oxygen providing that light and chlorophyll are present. This whole process is called "photosynthesis". If the plant needs the food at once it is sent through the plant as sugar; if not, it is stored as starch.

While photosynthesis is taking place in the plant something else is happening. It is the opposite of photosynthesis and is called "respiration" or breathing. Like animals, plants must have oxygen to produce energy. But plants need far less than animals. This energy is obtained from the slow burning or combustion of sugars. What use does the plant make of this energy? As with animals carbon dioxide is produced as a waste product, but in less quantities than is used in photosynthesis.

Fix up the fourth piece of apparatus and since the plant must be in the dark, cover the bell jar with a dark cloth. Air is drawn through the apparatus by means of pump or aspirator and the caustic soda removes the carbon dioxide from the air. The limewater in the tube "A" shows that the air passing into the bell jar contains no carbon dioxide. Does the limewater in the tube "B" remain clear, or does it become chalky? What is your explanation for what you see?



THE BUTTERCUP—

ALL flowers have the same essential parts. But in some they are more difficult to recognise than in others. In many of the highly cultivated garden flowers the various parts have been changed greatly from the original plant or flower from which they have been cultivated. So we shall study a very simple flower, one that grows wild almost everywhere in Britain in the summer. This flower is the buttercup, and if possible it will help to have one in front of you now.

We have seen how the roots provide water and some dissolved salts, how the stem carries food material through the plant, and how leaves make sugar and starch. But why do plants have flowers?

Study the diagrams and then identify the four main parts of your flower. Begin at the outside and work into the centre of the bloom.

First we have a ring of five separate green sepals, and their purpose is to protect the flower whilst in bud. Within the sepals is a ring of five yellow petals. Because they are bright they catch the eye, not only human eyes, but those of the insects as well. Carefully remove the petals. You will see that the upper side is bright and shiny and at the base there is a tiny pocket. Here a sweet juice, called nectar, is made, and it is this nectar that the bees collect and make into honey.

Now we come to the stamens. Are there the same number of stamens in each flower? Each stamen is made up of a thin stalk with a swollen yellow tip. These swellings burst open when the flower is in full bloom and yellow pollen comes out. These tiny grains, as we shall see later, are essential for the production of seeds.

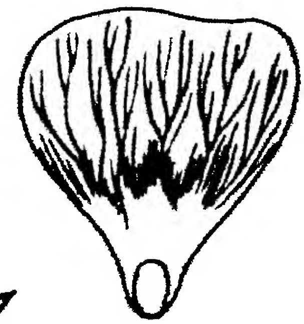
Right in the centre of the flower there are a number of green things which are called carpels. Take one of these and examine it under a magnifying glass, and try to decide for yourself how it is made up, cutting it open carefully to do so. You will see that it is hollow and consists of a little knob at the top, and inside there is a very small green pip, which later develops into a seed. This is known as the ovule.

All flowers can be said to follow this general plan, but may vary greatly in detail. When you can, examine a bluebell, a wallflower and a single poppy, and identify the various parts as you have done here with the buttercup.

—IS A SIMPLE FLOWER

These drawings are not to the same scale

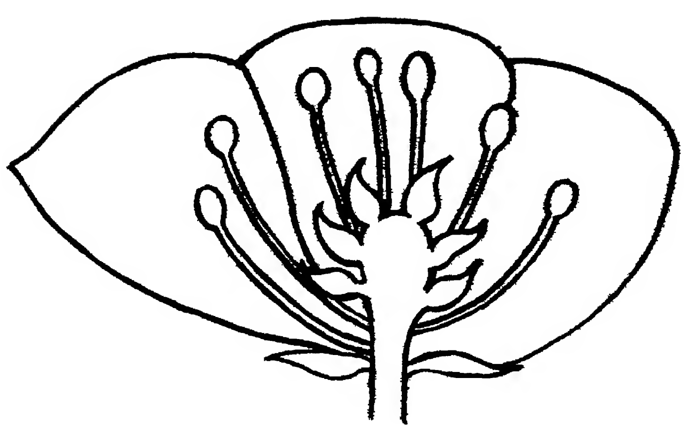
Stamen



Petal

Sepal

Carpel



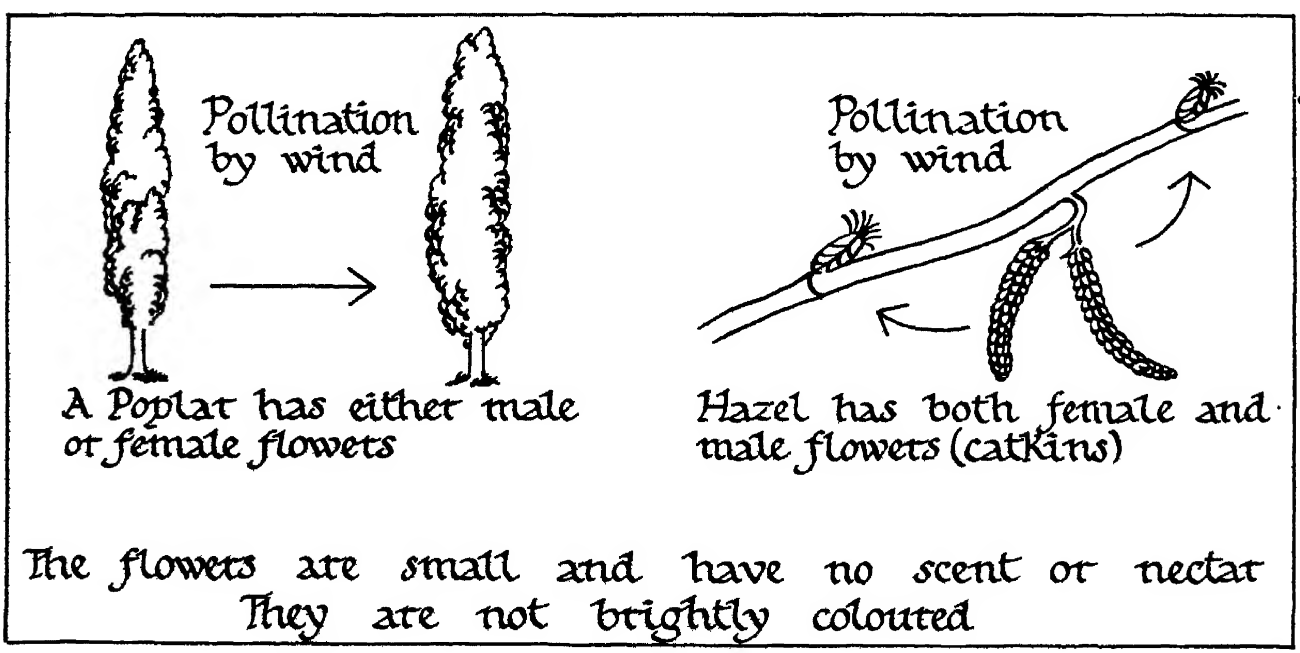
A simplified cross section of a Buttercup
Can you identify the parts?

THE PURPOSE—

THE purpose of the flower is to produce seeds which eventually give rise to new plants to replace the old ones as they die. The important parts of a flower are the stamens and carpels, for it is their job to form the seeds. This happens when pollen is transferred from the stamens to the ends, or stigma, of the carpels and thence to the ovules. This transference of pollen is known as pollination.

When the pollen reaching the stigma is from the same flower this is called self-pollination. If, however, the pollen comes from some other flower, then this is known as cross-pollination. Generally speaking cross-pollination produces better plants, and most plants are so constructed that this is the most likely means of producing seeds. How can self-pollination be avoided, or the chances of it taking place be lessened? Let us take for example the willow. Some plants have flowers which have no stamens, and other plants have flowers which have no carpels. The hazel on the other hand has both types of flower on the one plant. But perhaps the commonest method of preventing self-pollination is to have stamens and carpels on one plant ripening at different times.

How is pollen carried from one plant to another? The two main carriers are the wind and insects. Grass, nettles and some trees, such as the pine, rely on the wind. But, although this is a simple way, it is



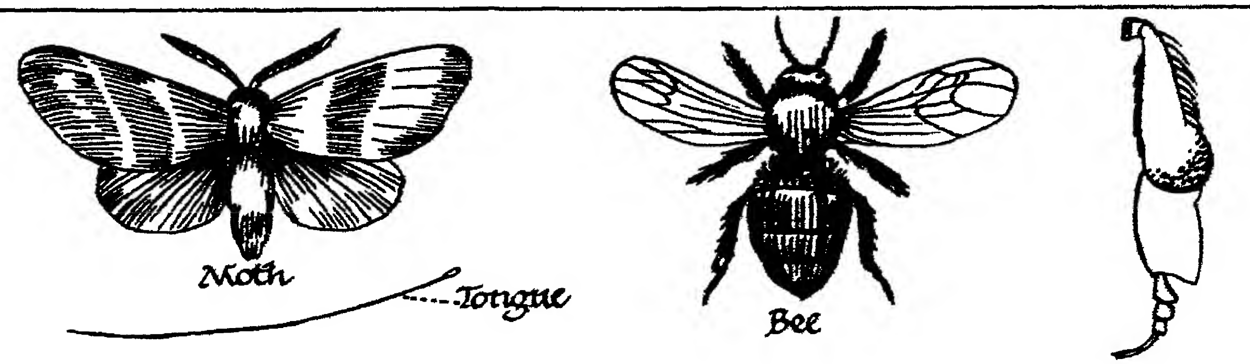
—OF PLANT FLOWERS

rather a hit and miss affair. For this reason pollen in these cases is produced in vast quantities so that at least a little of it reaches other plants; but most of the pollen is wasted. These flowers are generally small and not brightly coloured, and they have no scent or nectar.

Other flowers rely on insects. Bees, butterflies and moths carry the pollen from one bloom to another. The bright colours and the scent of the flowers attract them. They know that these flowers have nectar, and they go from one flower to the next searching for it, and sometimes for pollen as well. As they settle on the blooms they accidentally pick up pollen on their bodies, and as they move on they leave some of this pollen on the next flower they visit, and so on. The colours and scents are a means of ensuring that the insects are attracted to and continue to visit the same types of plant.

Flowers such as the tobacco plant, that are usually pollinated by moths, which are night-flying insects, are light coloured and more strongly scented. Can you say why? Do you know of any others?

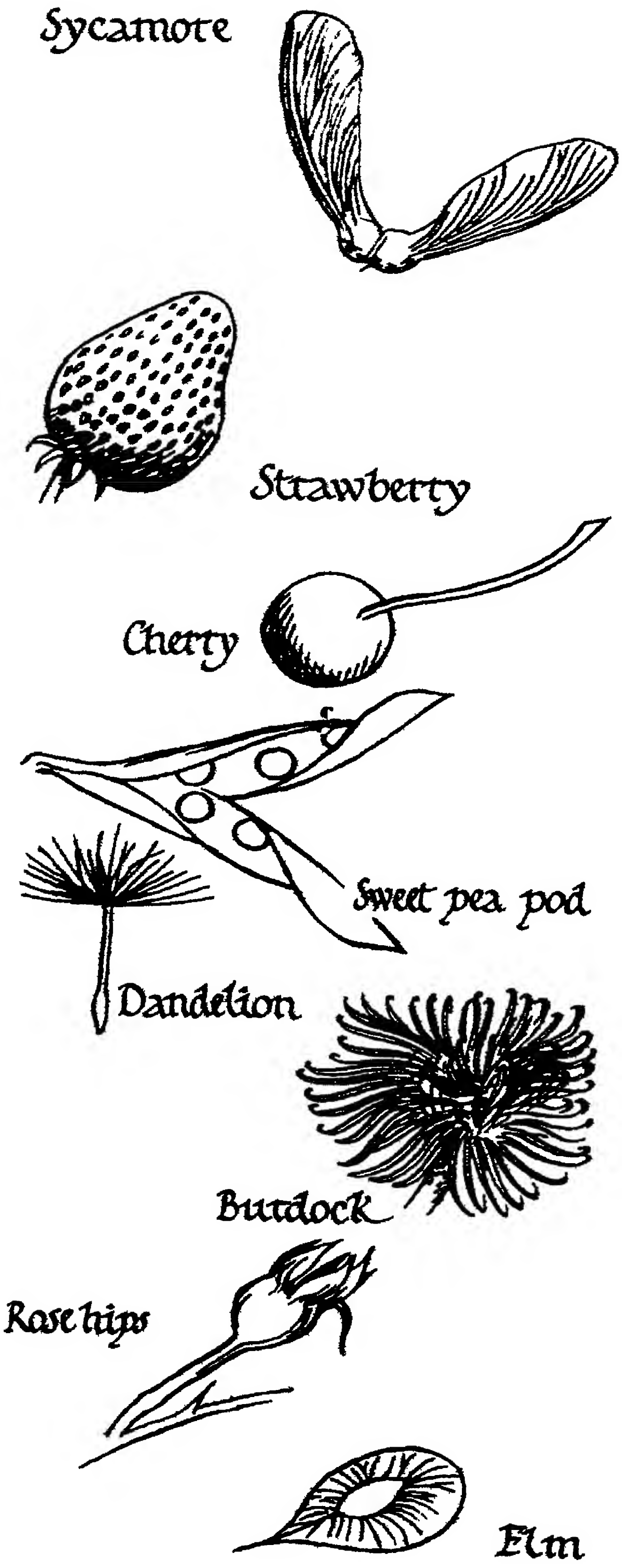
When a tiny grain of pollen falls on the stigma, it begins to grow, eventually part of it joining to part of the ovule. This process is called fertilisation and when it is complete the ovule begins to develop into a seed. What is artificial pollination, and where would you expect it to be done?



Insects that collect nectar have long tongues. They take pollen from one flower to another

Bees collect nectar and pollen. Some of the pollen is transferred to other flowers. The hind legs hold the pollen

Flowers that make use of insects have bright colours, scent and nectar



SEEDS ARE DISPERSED—

WHEN a seed develops it has certain needs. These must be provided for if the seed is to grow and replace the parent plant when it dies.

First there must be a reserve of food in the seed. It is on this reserve that the young plant lives until it has developed roots and leaves, and can make food for itself. This reserve, or store, may be large as it is in the horse-chestnut, or it may be small as in the case of the poppy seed. On the outside there is a hard coat which acts as protection until the plant begins to grow. This protection also varies. For instance, think about the hard shell on a nut, and the skin-like covering on a runner bean. Then sometimes the seeds are enclosed in a seed pod, which gives further protection. Can you give any examples?

Lastly seeds must be scattered. It would be useless if they all fell in the same place, say, in the shade of the parent plant, where they would not get enough light, and the competition for space would be too great and they would not survive.

Many seeds are scattered by the wind. But not all of them use the same method of dispersal. The seeds of the dandelion for instance have feathery parachutes, while

—IN MANY WAYS

other seeds are so small and light that they are blown quite a distance. Other wind-carried seeds are those which can be called winged seeds. Examples of these are the ash and the elm.

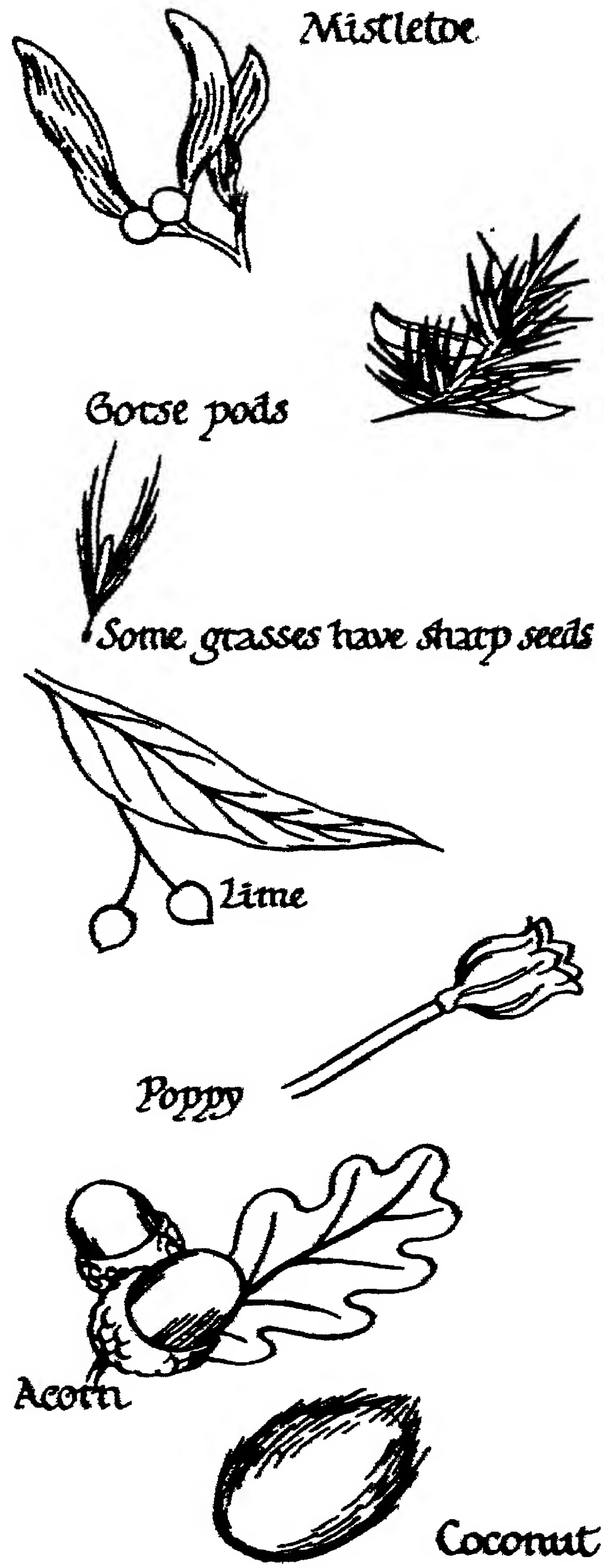
The seeds of some plants are scattered by animals. Those that have hooked spines often catch in the coats of passing animals and are often carried long distances in this way, while plants with attractive and juicy fruits rely mainly on animals and birds to scatter their seeds. These seeds pass through the animal or bird unharmed by reason of their hard protective coating and are often dropped many miles away from the parent plant.

Many plants have seeds contained in a pod which, when it is ripe and dry, explodes and so forces the seeds away.

Seeds of plants that grow in, or near water, are often distributed by the water, and these seeds have large air spaces in them so that they will float.

Look at the drawings of seeds: can you tell by looking at them how they are probably dispersed?

When the time is favourable make a collection of seeds of the different types. Why do plants produce such a large number of seeds?

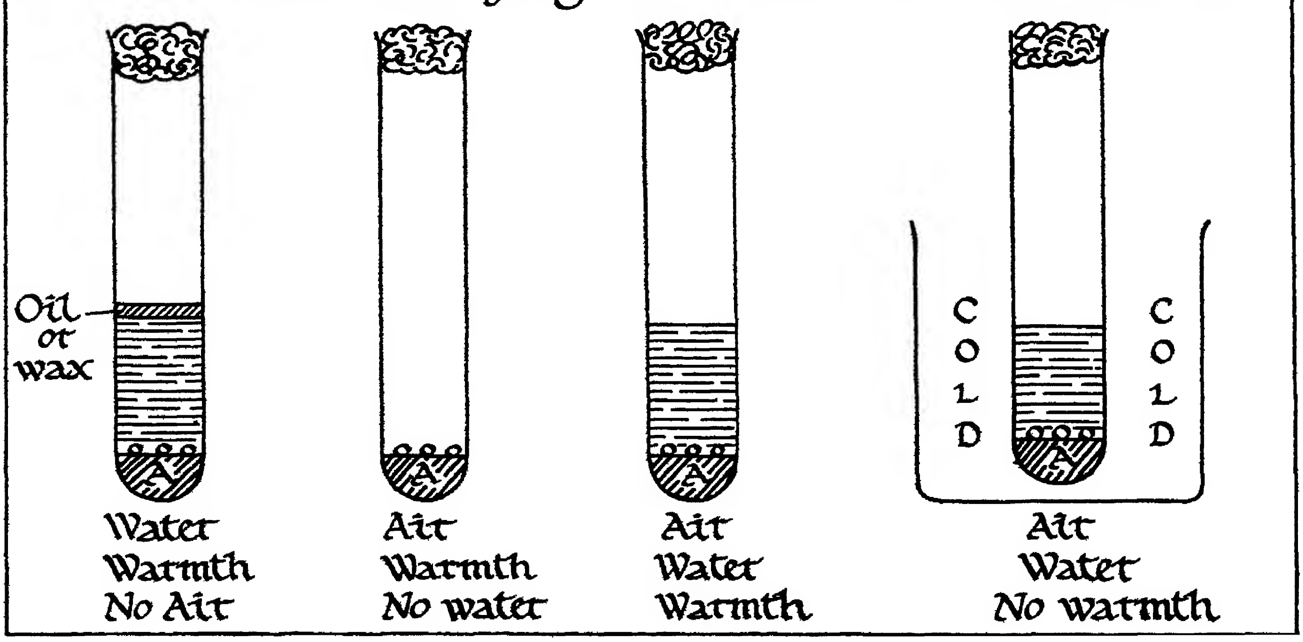


THE GERMINATION—

SEEDS kept in a warm room on a shelf, or in a packet will not begin to grow. We say they are "dormant". What conditions are needed before a seed begins to grow into a new plant? What are the conditions in the garden when we sow seeds? Sowing is usually done in autumn or spring, and at these seasons there is moisture in the ground. Moisture is certainly necessary, but it alone is not enough. Seeds planted in the open ground in winter would not germinate until the following spring, and then only if they survived in the ground and did not rot away. For germination seeds must have warmth, and this is supplied naturally from the sun, or artificially in a greenhouse. Then oxygen is necessary too. Often we are disappointed because our seeds do not grow. This sometimes happens because we plant too deeply in the ground where it is not warm enough, and where there is not enough air, and oxygen. These necessary conditions required for seeds to germinate can be confirmed if you do the test-tube experiments set out here. Use cress seeds for this experiment.

Examine some beans and peas that have been kept from the last season. You see they are hard and shrivelled. Cut them open and see what they look like inside. Make drawings of them in your record books. Now put them into water and let them soak for twenty-four hours. What happens?

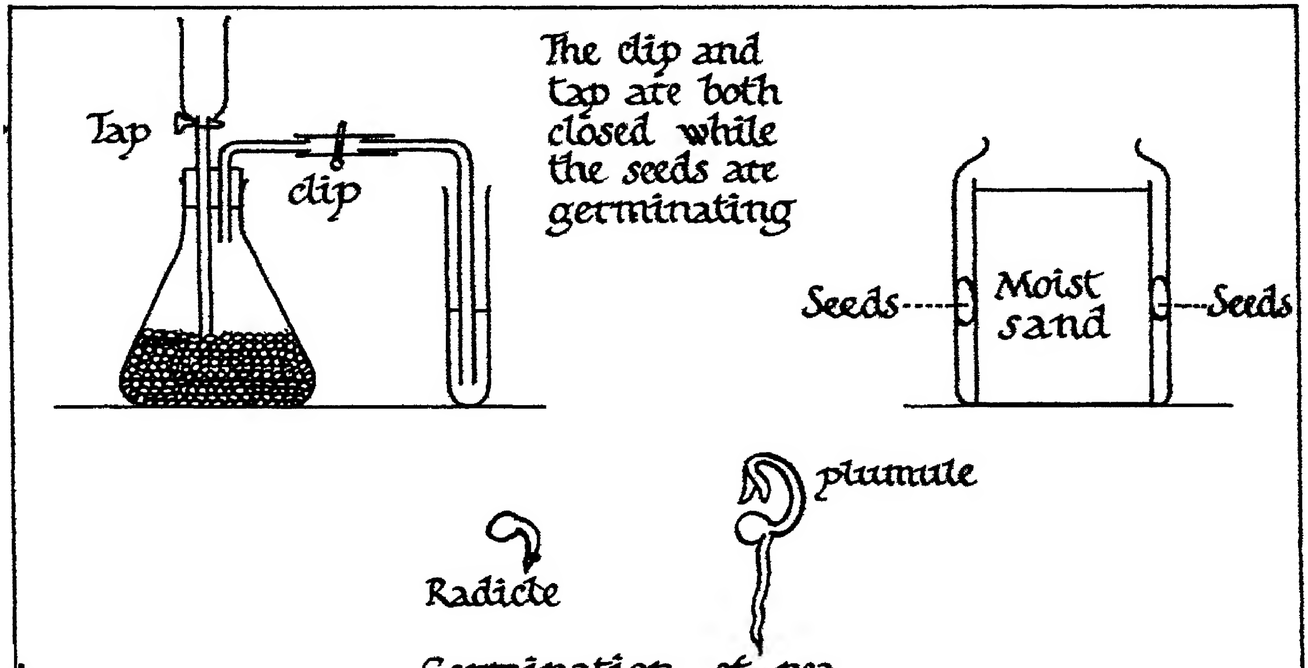
A is a cotton wool plug on which the cress seeds test



—OF SEEDS

When growing takes place energy is needed and this comes from food and oxygen. Carbon dioxide is formed when this happens, as a waste product. Does this also happen when seeds begin to germinate? We have said that oxygen is needed, but is carbon dioxide produced? Fit up the apparatus shown, and half fill the small flask with peas that have been soaked in water. Leave them for twenty-four hours at least and then pour water through the funnel so that it forces the air out of the flask through a tube of limewater. Was carbon dioxide formed? We can repeat this experiment, and this time, after the peas have been left for twenty-four hours, plunge a lighted taper into the flask. Does it go out? Why?

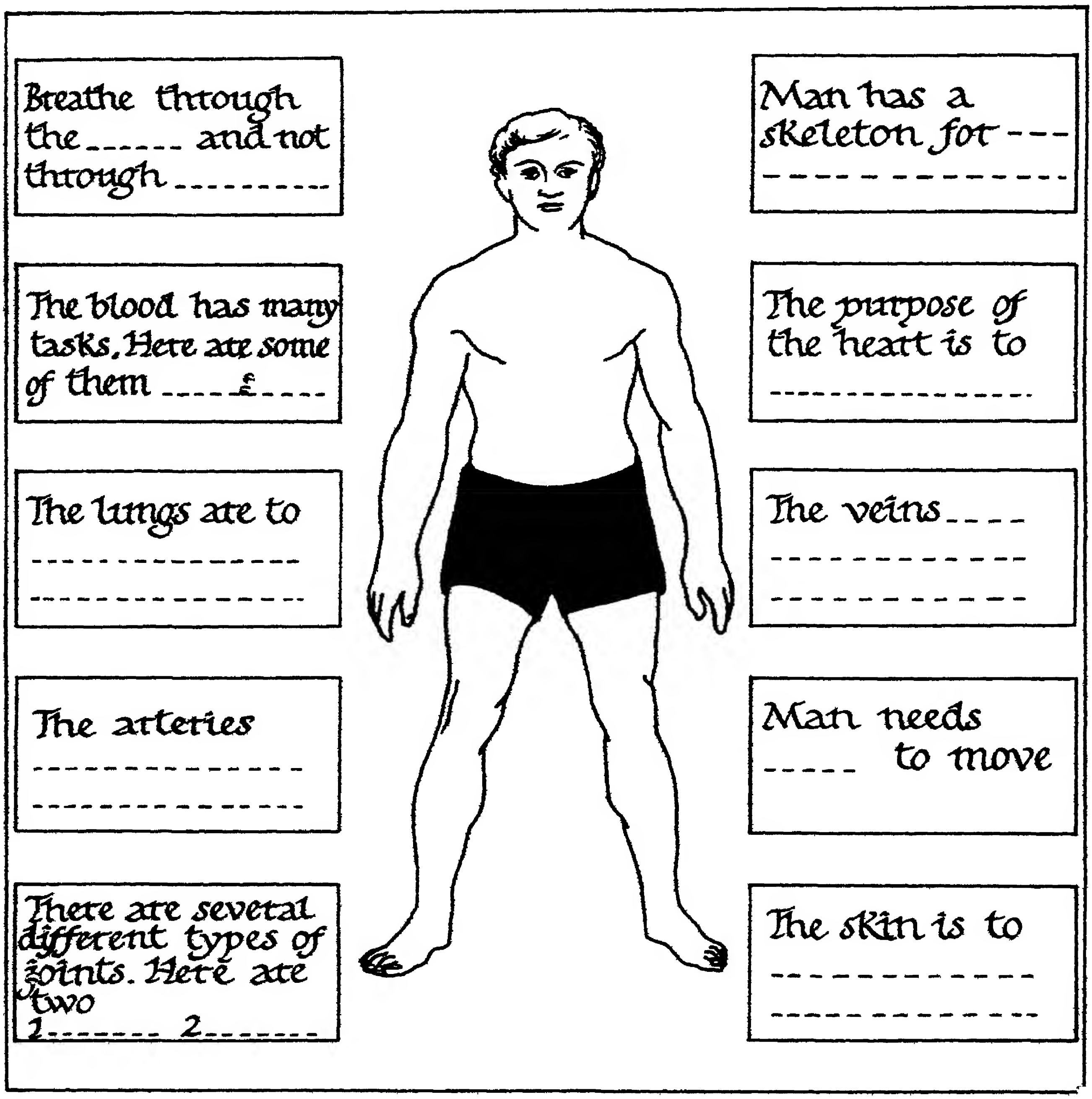
The changes that take place during germination can easily be seen if you do the following experiment. Line a glass jar with blotting paper and fill the centre with sand and moisten it. Using the seeds of the broad bean, soak them first, and then push them in position between the walls of the jar and the blotting paper. Keep a record of the progress they make, using drawings to illustrate, and noting the dates. Using different varieties of seeds repeat this experiment and table your observations in the same way in your record books. From these tables you will see at a glance the differences between the ways in which seeds germinate.



Germination of pea

TWO DIAGRAMS TO COPY—

WE have covered a lot of new facts while we have been talking about our bodies and some of the common plants around us. Some of these facts will be new to you, some you may already know. But how much can you remember? Copy these two diagrams into your record books, leaving enough space to fill in the missing parts. Do not



.—AND A PICTURE QUIZ

refer back to your books. Fill in the gaps in pencil first. When you have done this check your answers, and you can then ink in the correct words. Do not worry if you cannot make your flowering plant and your human body perfect, but it is important that the parts marked are in the correct positions. Do not mark this book in any way.

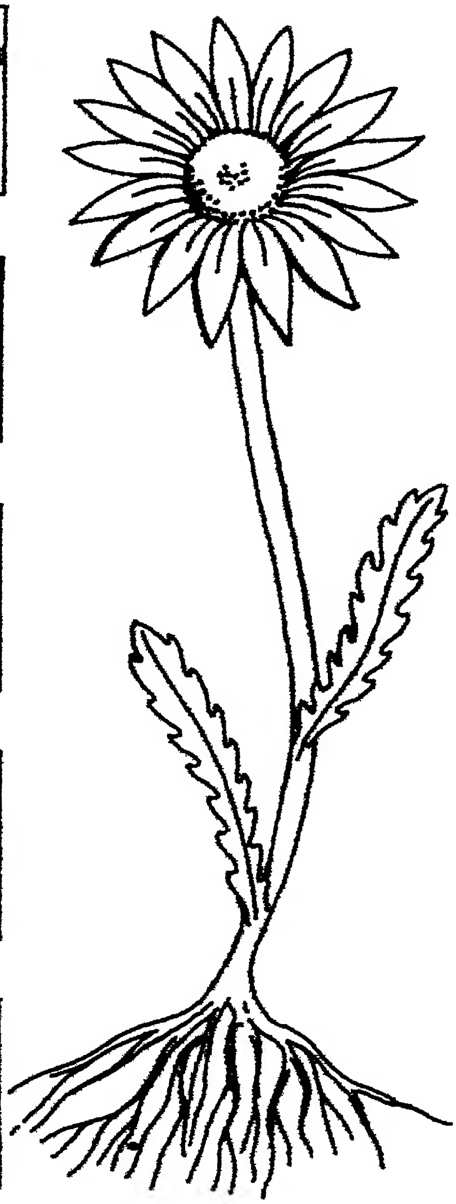
Light and warmth are needed for ______________

Stamens are ____________ ____________

Insects help the flower by _____ ______________

Plants do not move because. ______________

Water enters through______ ______________



Flowers are coloured because ________________

Insects come to collect ________ ____________

Plants have no digestive systems because__________

Plants need leaves for making_____ ______________

Some plants such as______________ store food

BY now we have almost reached the end of another school year and you are probably thinking of holding an end of term exhibition. You should have made several models that you can show, and there are certainly many demonstrations on such topics as light and colour that would be very effective. Whatever you do I am sure that it will be successful because this subject lends itself so well to demonstration.

Next year we will see how recent developments in science are helping us. But at the same time we have to realise that these developments also tend to make life more and more complicated in that all of our modern methods depend upon more people, who must be more highly trained and skilled than in the years gone by.

Travel in space is much nearer a reality than it was only a few years ago, while men have for some time been thinking about the benefits that the atom can give us, rather than thinking solely in terms of destruction. From this work, which was speeded up by war, come further ways of combating disease, and alternative sources of power to offset the rapid using up of our natural resources.

This means that science is affecting more and more people in more and more ways. One can rarely read a newspaper today without becoming aware of this fact. An understanding of the modern everyday uses of science, therefore, becomes even more necessary in order to appreciate the effect of these developments on our daily lives.